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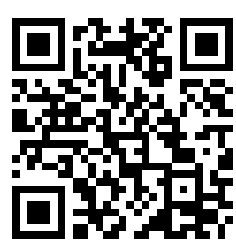

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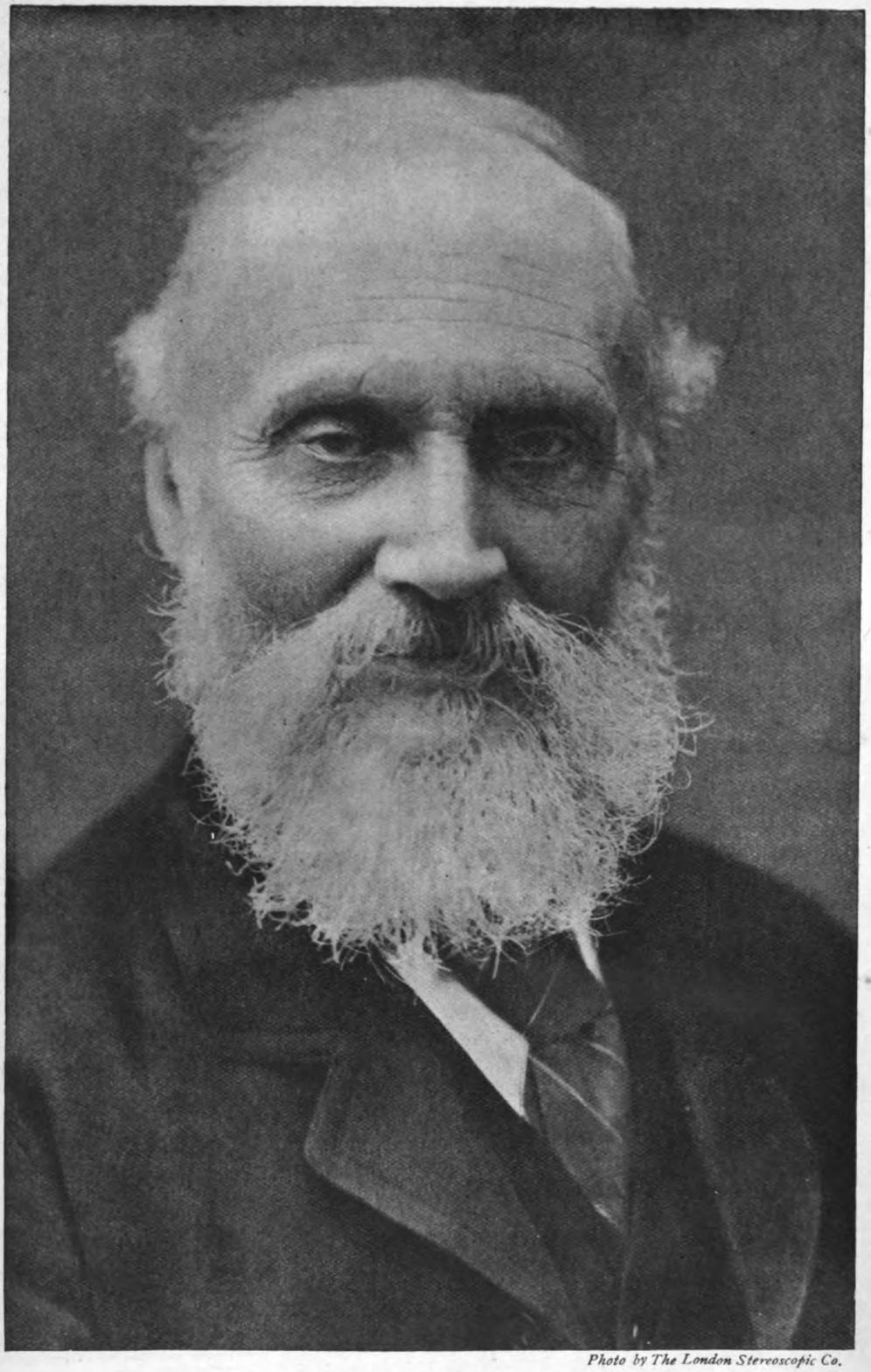

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LORD KELVIN.

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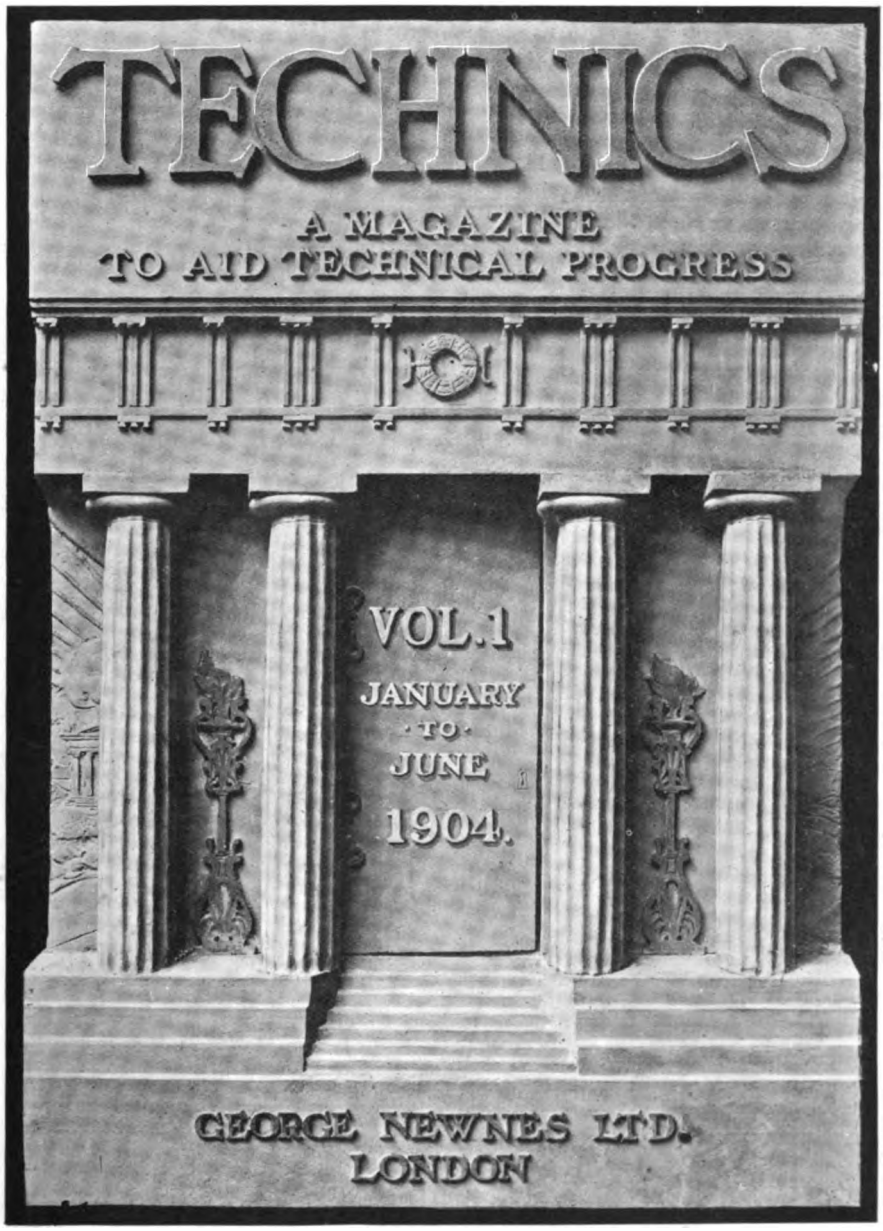

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TECHNICS

A MAGAZINE FOR TECHNICAL STUDENTS.

VOL. I. JANUARY, 1904. No. 1.

LORD KELVIN.

No more fitting frontispiece for the first number of this Magazine could have been selected than the portrait of Lord Kelvin, G.C.V.O., O.M., P.C. He is not merely the acknowledged "head and front" of British science, but, by the universal consent of the scientific men of all countries, is declared to be the greatest living physicist. Born in June 1824, the son of a distinguished Professor of Mathematics, and educated at home with his brother, who also achieved eminence as a scientist, Lord Kelvin gave promise of extraordinary ability by matriculating at the University of Glasgow when ten years old; he entered Peterhouse, Cambridge, seven years later, and took the best mathematical degree of his year—Second Wrangler and first Smith's Prizeman—when twenty-one years old. After a year of study under Regnault in Paris, William Thomson became Professor of Natural Philosophy at Glasgow University in 1846, held that position for fifty-three years, and achieved a world-wide reputation as a mathematician and discoverer in physical science. His influence on the work done by his students, and by other men of science throughout the civilised world, cannot be over-estimated. His contributions to applied science have been no less notable than his purely scientific researches and discoveries. He is claimed as an eminent engineer by engineers, no less than as a leader by the workers in pure science. More than fifty-five years ago he was associated with Joule in founding the modern Dynamical Theory of Heat—the basis of all subsequent developments in steam and heat engines. Electricity owes much to his research and inventive powers in all its recent applications. For half a century he has been prominent in all matters connected with telegraphy, especially submarine telegraphy. To him we owe the most efficient and beautiful instruments, devised for transmitting and receiving messages, as well as all kinds of instruments for electrical measurements. The determination of electrical standards is primarily due to him; and his experiments of 1853 greatly influenced the later work of Herz, Oliver Lodge, Marconi, and others, from which has resulted the introduction of wireless telegraphy. His improved form of mariner's compass, and his novel sounding apparatus—capable of determining depths of water while a ship proceeds at high speed—have proved of immense advantage to ocean navigation in these days of rapid ocean transit. His investigations respecting tidal phenomena, and invention of instruments for recording and measuring the rise and fall of tides, are of great value.

This statement affords no adequate idea of the immense range and importance of the illustrious life-work of Lord Kelvin. The scientific world has showered upon him its highest possible distinctions, in recognition of his unrivalled eminence. But these honours have left him still modest and sympathetic, making little claim to personal credit for great achievements, while highly appreciating the work of others. Now that he is nearing four-score years his mind retains its remarkable power and elasticity, while his kindliness is as great as ever. It has been well and truly said that "nothing seems to give him so much pleasure as an opportunity to acknowledge the efforts of the humblest scientific worker." We may add that there is no warmer friend to scientific and technical training. The promoters of this Magazine deem it an honour to be assured, that the greatest living man of science is of opinion that it should prove very interesting and useful, and wishes it all success.

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PROGRESS OF SCIENCE AND TECHNOLOGY.

A PAPER entitled "The Metrical System of Weights and Measures" was read before the Royal Statistical Society on Tuesday, December 15th, by Mr. Alex. Siemens. It was pointed out that the metric system was in great measure due to the arguments of James Watt, who took the subject up in the year 1783. This should go far to reconcile those who object to the metric system on the ground that it was "made abroad." Mr. Siemens stated that in France and Germany all of the older systems of weights and measures are now practically obsolete. As regards the expense of changing from our present system to the metric system, Mr. Siemens urged that this could be minimised, so far as relates to screw-cutting machinery, by the use of suitable change wheels.

The Metric System.

It is reported that, early next session, a bill will be introduced into the House of Lords to render compulsory the adoption of the metric system of weights and measures throughout the United Kingdom. It is understood that the first reading of this bill will be moved by Lord Belhaven, and seconded by Lord Kelvin.

Compulsory Adoption of the Metric System

It is gratifying to hear, from time to time, that the scheme for a great technological institute in London, which has been associated with the name of Lord Rosebery, has not fallen through. After distributing the prizes at the Borough Polytechnic on December 4th, Mr. Haldane, K.C., M.P., stated that conferences had taken place with the representatives of the Government, of the great City companies, and of the London University, and it was hoped that a scheme worthy of the great Metropolis would eventually be forthcoming. Mr. Haldane further stated that every care would be taken to prevent overlapping, the aim of the Rosebery trustees being to fill up the educational gaps which exist at present. Thus the work of the Royal College of Science, of the City and Guilds Institute, and other similar educational institutions, will in no way be interfered with. At the recent annual dinner of the Institution of Mining and Metallurgy, Sir William Anson, Parliamentary Secretary to the Board of Education, promised the cordial support of the Board of Education to the Rosebery scheme, and announced that a special Board had been appointed to inquire into its relations with the Royal College of Science.

The Technical High School for London

The agents for the promotion of the proposed Yorkshire University have received a communication from the Privy Council, in which it is announced that their lordships agree to recommend the grant of a charter, subject to the condition that the West Riding County Council makes a substantial subvention towards the University, and the promoters undertake to raise a capital of £100,000 by the earliest possible date. It is pointed out that the proposed title of the University, the "Victoria University of Yorkshire," is unsuitable, as implying a possessory interest in the whole of Yorkshire, besides which it might lead to confusion with the Victoria University of Manchester.

The Proposed Yorkshire University

Nature for December 10th contains a most interesting account of the Cavendish Laboratory at Cambridge. In 1870 the Duke of Devonshire built and equipped this important institution, which he named in honour of his great-uncle, the Hon. Henry Cavendish, F.R.S.—that eccentric scientist whose unpublished researches covered so much of the ground afterwards independently explored by Faraday. From the start, the Cavendish Laboratory has been a most important centre of research. Here Maxwell, after planning and equipping the laboratory, carried out many important investigations. On Maxwell's death Lord Rayleigh became Cavendish Professor of Physics, and carried out his classical researches on the values of the volt, the ohm, and the ampère. In 1884 Lord Rayleigh accepted the position at the Royal Institution rendered vacant by the retirement of Tyndall, and Professor J. J. Thomson was appointed Cavendish Professor at the early age of twenty-six. Professor Thomson had previously been impressed by a statement of Maxwell's, that the nature of electricity would probably be discovered in studying electrical discharges in the vacuum tube. This may be said to have determined the

Research Work at Cambridge

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course of research work which has now been for many years in progress at the Cavendish Laboratory. One of the most striking discoveries which have resulted from this course is that the Kathode Rays produced in a vacuum tube consist of streams of charged particles each possessing about one one-thousandth part of the mass of a hydrogen atom. Many philosophers had previously theorised on atomic structure, and some had even gone so far as to predict that atoms might be capable of partial or total disintegration, but Professor Thomson was the first investigator to obtain quantitative evidence of an ultra-atomic state of matter. Professor Thomson's methods of research have recently been extensively used in connection with the study of that eccentric element, radium. At present there are nearly thirty research students working under Professor Thomson in the Cavendish Laboratory. These students have come to Cambridge, not alone from the various Universities of Great Britain and Ireland, but also from Canada and Australasia, from the United States of America, and from France, Germany, and Austria. Many now well-known physicists owe their first inspiration to Professor Thomson; among these may be mentioned C. T. R. Wilson, Maclelland, Rutherford, Zeleny, Townsend, Langevin, H. A. Wilson, Maclennan, and Strutt. To a great extent Professor Thomson has realised, at Cambridge, the ideal research university which the most keen-sighted Americans are striving after. It is significant that Professor Thomson is nowhere held in higher esteem than in the United States, where he has twice, by invitation, delivered important courses of lectures.

The Work of J. J. Thomson

On November 13th Sir Oliver J. Lodge read a paper before the Physical Society of London on "Means for Electrifying the Atmosphere on a Large Scale." In 1884 the author showed an experiment, at a meeting of the British Association in Montreal, in which smoke was caused to condense and fall in fine particles by electrical means. At opposite sides of a vessel with glass sides were placed two pieces of wire gauze, connected to the terminals of an electric machine. When the vessel was initially full of smoke, the latter was rapidly condensed so soon as the electric machine was put in motion. In a similar manner a mist was condensed, producing fine rain. Since the above date Sir Oliver Lodge has attempted to disperse ordinary fogs by similar means. A high mast was erected on the roof of University College, Liverpool, and electricity was conveyed to pointed conductors at its extremity. In some experiments flames were used instead of the pointed conductors. A very high potential was required, which was obtained by using a Wimshurst machine. Upon one occasion the discharge of electricity from a flame was sufficient to keep a clear space of from 50 to 60 yards radius in the fog. Sir Oliver Lodge now proposes to use a high tension alternating electric current, after rectification by means of an arrangement of Cooper-Hewitt lamps, to disperse fogs on a much larger scale. It is proposed to erect masts on either side of the Mersey, those on one side carrying flames charged positively, while those on the opposite side carry flames charged negatively. By this means it is considered possible that the Mersey may be kept clear of fogs even in the thickest weather. Dense fogs are dissipated even more quickly than those of a lighter character. The potential required is above 100,000 volts.

The Electrical Dissipation of Fogs

At the Institute of Electrical Engineers on November 26th, Mr. W. Hibbert read an interesting paper on the Edison accumulator. This accumulator consists of two light steel frames, containing perforated steel pockets. The pockets in the positive plate are packed with nickel oxide, while those in the negative plate are packed with iron oxide. The medium between the plates is a 20 per cent. solution of caustic potash. On charging, the active material in the negative plate is reduced to metallic iron, while that in the positive plate is converted into nickel peroxide; on discharging, the iron becomes oxidised, the nickel peroxide becoming reduced to nickel oxide. The E.M.F. is approximately 1·35 volts. A standard size of cell for automobile work is 13 inches high and 5·1 × 3·5 inches horizontally; such a cell weighs 17·8 lbs. The output at 60 ampères is about 210 watt-hours, thus giving about 11·8 watt-hours per lb. The internal resistance is about 0·0013 ohm. Mr. Hibbert has tested the cell in the laboratory, and also in an automobile run over about 500 miles in one month. The laboratory tests proved that the cell is free from many of the objectionable peculiarities which render a lead storage cell so difficult to keep in order.

The Edison Accumulator

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Thus a cell with a normal discharge rate of from 30 to 40 ampères gives 80 per cent. of its normal ampère-hours when the discharging current is equal to 200 ampères. A cell which had been short-circuited for 48 hours recovered its original capacity after two charges, and was apparently no worse for this severe treatment. Further, overcharging, even with a current of four times the normal value, produced no ill effects. The cell is also uninjured if left for a considerable time after charging. The trial on the road proved very satisfactory. The shaking produced no ill effects, and steep hills were successfully climbed, the current rising on one occasion to 150 ampères without injuring the cells. The efficiency of the Edison accumulator is, however, inferior to that of a lead cell, varying from 66 per cent. when charge and discharge takes place at the rate of 30 ampères, to 50 per cent. when charge occurs at the rate of 177 ampères and discharge at the rate of 60 ampères.

The Gilbert Tercentenary

The usual fortnightly meeting of the Institution of Electrical Engineers, on Thursday, December 10th, happened to fall on the three hundredth anniversary of the death of Dr. William Gilbert, of Colchester; accordingly, the first part of the meeting was devoted to a formal presentation, to the Mayor and Borough of Colchester, of a picture of Gilbert showing his electrical experiments to Queen Elizabeth. Dr. Gilbert has long been acknowledged as a pioneer in science; his world-renowned book, "De Magnete," was published as early as 1600. Prof. S. P. Thomson thus describes his contributions toward our present knowledge of magnetism:

> Trying the properties of loadstones in innumerable experiments lasting over many years he was led to several notable discoveries, and to one generalisation of immense importance. He discovered the augmentation of the power of a loadstone by arming or capping it with soft iron cheeks. Gilbert called such a cap an *armatura*, the first occurrence of the term. . . . Gilbert also discovered the screening effect of a sheet of iron; the method of magnetising iron by hammering it while it lies north and south; the destruction of magnetism by heat; and the existence around the magnet of an "orbe of virtue"—that is to say, a magnetic field. He perfected the dipping needle of the Norman and other instruments of observation. He collected data as to the declination and inclination of the compass in different regions. Using loadstones of many different shapes, he observed their actions on one another and on compass needles. In particular he studied the magnetic properties of a globular loadstone or *terrella*, and found that compass needles were directed toward its poles, and dipped at various angles over its surface, just as compass needles do at various regions of the earth's surface. Generalising from small to large, he advanced the entirely novel idea that the globe of the earth is itself a great magnet, thus laying the foundations of the science of terrestrial magnetism.

Testing Electric Generators by Air Calorimetry

In many cases the efficiency of a generator can neither be tested by a brake nor by the Hopkinson method. On November 26th Professor Threlfall, M.A., F.R.S., described a method applicable in such cases before the Institution of Electrical Engineers. Professor Threlfall encloses the generator in an air-tight chamber, through which air is pumped at a measured rate. The temperatures of the air on entering and leaving the chamber are directly observed, while the specific heat and mass of the air passing through per second being known, the energy dissipated per second in the form of heat can be calculated. The electrical output can, of course, be determined by the aid of a volt-meter and an ammeter. Then the efficiency can be obtained with considerable accuracy. This method should prove of great value to electrical engineers.

Wireless Telegraphy

The practical utility of wireless telegraphy was recently illustrated when the *Kroonland* became disabled west of the Fastnet on her way from Antwerp to New York. The captain was able to communicate particulars to the agents at Antwerp, and to receive instructions from them in less than an hour and a half. Many passengers also sent messages to their friends and relatives, assuring them of their safety.

Sparking Devices for Gas and Oil Engines

The present popularity of automobiles and motor cycles has caused much attention to be devoted to various spark ignition devices. It is interesting to note that Lenoir's gas engine, made in 1860, had a trembling coil and internal spark gap, not unlike that used at present. Lenoir's engine was killed by extravagant praise, followed by not wholly deserved discredit. Crossley's Otto engine next popularised flame ignition methods, which in the long run were supplanted by the hot tube ignition method. It was then found that iron tubes become choked internally with carbon, and that porcelain tubes frequently became fractured. Platinum tubes proved satisfactory; although they

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cost £2 each when new, a disused tube could be sold for 35s. When, however, the hot tube method of ignition was tried on motor cars, several persons were burnt to death through its use; thus it happens that after more than forty years spark ignition methods have again come to the front. Their chief disadvantage appears to lie in the tendency to miss fire, and this may often be traced to bad design, especially of the sparking plug. Further, incomplete combustion in the cylinder will cause the porcelain of the plug to become coated with carbon, and this introduces leakage, which in its turn prevents the formation of a spark. It requires a high potential in the gap before a spark can be formed, and leakage carries the electricity away before the potential can rise to the required value. By accident, some workmen in Panhard's factory found that an external spark gap greatly improved the regularity of ignition. This observation has been endorsed by many in England and abroad; but the explanation of its action does not appear to be so generally known as its general efficacy. At first sight it would appear, that adding to the resistance of the sparking circuit by including an extra spark gap, is an eccentric way of seeking to promote sparking. The true explanation of the advantage gained appears to be as follows. If the internal spark gap is leaky, as must always to a certain extent be the case, no continuous flow of electricity can occur until the spark can jump the clean external spark gap. When the outer spark occurs, the sudden rush of electricity to the internal spark gap produces a bright spark, since the rate of leakage is now insufficient to carry the electricity quietly away as it arrives.

Sparking Devices

Similar devices have been used in physical laboratories for many years. Finally, it may be said that students possessing motor cycles have at their disposal the opportunity of making valuable investigations, and perhaps of greatly improving our present arrangements. A careful investigation of the relation between the nature of the spark and the output of the engine is badly needed. There is also room for an improved spark plug.

PERSONAL ITEMS.

TWO of our greatest men have recently been removed from us by death. Sir Frederick Bramwell, Bart., died on November 30th, in his eighty-sixth year. Mr. Herbert Spencer died on December 8th, at eighty-three years of age. Our educational ideals have been greatly influenced by Mr. Spencer's writings, while Sir Frederick Bramwell's energy and balanced judgment have contributed to the success of many and diverse educational schemes. Both lived through a period which will always be remembered for its rapid progress in science, and to the work of each may be traced much of the advance which has been effected.

A BILL has been authorised by the Minister of Public Instruction, Paris, which provides for the creation of a Chair of General Physics at the University of Paris, as a special honour to M. Curie for his work in the discovery of radium.

THE ANNUAL General Meeting of the Association of Technical Institutions will be held at the Leathersellers' Hall on Friday, January 29th, under the presidency of Sir John Wolfe Barry, K.C.B., when the president-elect, Sir John Gorst, will deliver an address, after which the Association will proceed to elect a Secretary in place of Professor Wertheimer (retiring) and a Treasurer in place of Alderman Martineau (retiring). In addition, new members of the Council will be elected to replace seven members who are retiring.

THE FIRST of a course of ten Saturday morning lectures on "Temperament, Type, and Character in Education" will be delivered at King's College, Strand, by Professor John Adams, of the University of London, on January 16th. These lectures are free to teachers, who should apply for cards of admission to Professor Adams, 5, Clement's Inn, W.C.

THE PHOTOGRAPHIC and Printing Crafts Department of the Municipal School of Technology, Manchester, arranged early in the session for a series of special lectures, free to students attending any classes in the

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Institute. On January 15th Mr. Henry Cadness will deliver a lecture on "Harmony of Colour in Typographic Arrangement." On January 29th Mr. G. L. Hoyt will lecture on "The Construction and Working of the Miehle and Century Presses." On February 5th Mr. C. Doughty will lecture on "The Linotype Composing Machine." On February 12th Mr. J. Fazakerly will lecture on "The Ornamentation of Bound Books." The lectures will commence at 7.30 P.M.

THREE LECTURES, which should be particularly interesting to technical students, will be delivered on Thursdays, February 25th, March 3rd and 10th, by Professor Callendar, MA., LL.D., F.R.S., at the Royal Institution of Great Britain, Albemarle Street, W.C. The title of these lectures is "Electrical Methods of Measuring Temperature." Each lecture will commence at 5 P.M.

THE FRIDAY EVENING Lectures at the Royal Institution will commence on January 15th, when a discourse on "Shadows" will be delivered by the Right Hon. Lord Rayleigh, D.C.L., F.R.S., etc.

AT THE FIFTH meeting of the Students' Engineering and Metallurgical Society, Sheffield Technical School, which was held on December 11th, Mr. H. Slater read a paper on "Refractory Materials." After describing the refractory materials in general use, the manufacture of steel-making crucibles and silica bricks was described. A discussion followed, in which many students took part.

AT THE SECOND ordinary meeting of the Faraday Society, which was held on December 8th, a paper on "The Total and Free Energy of the Lead Accumulator" was read by Dr. Lehfeldt, Head of the Physics Department at the East London Technical College.

MR. EDGAR SENIOR, who is well-known as a lecturer on Photography at several London Polytechnics, is forwarding a series of specimens of Lippmann colour photographs to the forthcoming St. Louis Exhibition. Mr. Senior is also sending a number of photo-micrographs of Lippmann films, showing their laminated structure.

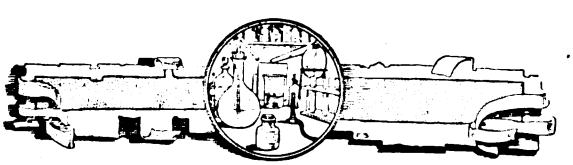
MR. W. HIBBERT, whose recent tests of the Edison Accumulator are at present exciting so much interest, is the Head of the Physics Department at the Regent Street Polytechnic. Mr. Hibbert's name is well known in connection with numerous investigations on the lead accumulator, carried out by him and the late Dr. Gladstone, F.R.S.

THE FIRST STUDENTS' meeting of the Institution of Civil Engineers was held on December 4th, Sir William White, K.C.B., F.R.S., in the chair, when a paper on "Artificial Draught as applied by Fans to Steam Boilers," was read by Mr. W. H. A. Robertson, Stud. Inst. C.E.

ON NOVEMBER 23rd, Mr. S. R. Kay, A.M.I.C.E., addressed a meeting of the Yorkshire College Engineering Society, Leeds, on the subject of "Railways and their Protection from Underground Workings." The subsidence of the ground from under which coal has been removed was dealt with, especially with regard to its effect on railway lines.

AMONG the successful candidates at the examination for B.Sc., held by the London University in October, two in the first division, and sixteen in the second division were students at the various London Polytechnics.

[*Authentic contributions to these columns are invited.*]



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"CHARLOTTENBURG," THE BERLIN TECHNICAL HIGH SCHOOL.

By Professor W. E. DALBY, M.A., M. Inst. C.E.

THE Berlin Technical High School stands in Charlottenburg, facing the main road from Berlin. The size and fine proportions of the buildings, the tasteful decoration of the façade, and the spacious entrance way impress the most casual stroller with the feeling that it is a place housing something which the German people hold to be of supreme national importance. Without enquiry the building might well be taken for the national museum of a great empire, or the parliament house of a great people; few would guess that it is the home of an organisation devoted entirely to the teaching and the cultivation of applied science.

There must be no illusion in connection with the term "high school." The range of education associated with the name in this country cannot be compared with the range established in the technical high schools of Germany. At Charlottenburg in particular the education throughout is of university standard. Students are not admitted to the school until they are eighteen years of age, and then the full course lasts four years.

The stated object of the Berlin Technical High School is to give a specialised training in industrial subjects founded on a preliminary scientific training, and also to foster the cultivation of all kinds of knowledge bearing upon technical subjects. In other words, the aim is to teach and equally to advance the sum of human knowledge by research—a combination of purpose which has produced men from the great technical institutions and universities of the land, who have enabled Germany, according to good authority, to ruin our industry in the organic chemical compounds, and to threaten our indigo planters with extinction: men who have given Germany a pre-eminent position in the manufacture of optical glass, and men who have enabled her shipbuilders to advance with confidence to the building of ships which hold the record of the Atlantic for speed, and which exceed in power anything which up to the present has been seen on the North Atlantic.

The twofold aim of the school should be carefully noted. In the majority of the technical institutions of the country endeavour is concentrated on teaching, almost to the exclusion of research. No special provision is made for research work, and in the cases where it is done it is carried out in spite of difficulties, hampered for want of funds and apparatus, and meets with little sympathy from the ruling powers of the institution. The Royal Institution is the only place in the British Isles which exists primarily for research work. Here Faraday discovered, by a series of brilliant experiments, the laws of magneto-electric induction, and it is to our national discredit that our share in the development of these principles into the modern practice of electrical engineering has been so small. This is mainly due to our defective system of technical education and our traditional system of training engineers in the practice of engineering without at the same time insisting that they should be familiar with the principles upon which the practice is based.

The school at Charlottenburg is a State institution and is under the immediate direction of the Minister for "Ecclesiastical, Educational, and Medical Affairs," known more shortly as the Culture Minister.

Prior to 1884 there existed two technical institutions in Berlin known respectively as the "Bauacademie" and the "Gewerbeacademie." These were brought gradually into closer relation with one another until, in 1876, it was decided to combine the two schools into one and to erect a building large enough to accommodate 2,000 students.

Building operations were commenced in 1878 on the site of the old Hippodrome at Charlottenburg, the extent of the site being about 220 acres. The original design consisted of the main building shown in Figure 1, and in plan Figure 2, and a chemical laboratory placed somewhat to the east of it. This design was carried out, and the Technical High School was inaugurated on the 2nd November, 1884, by His Imperial Majesty the Kaiser.

The main building is some 750 feet long and 300 feet deep. There are four stories.

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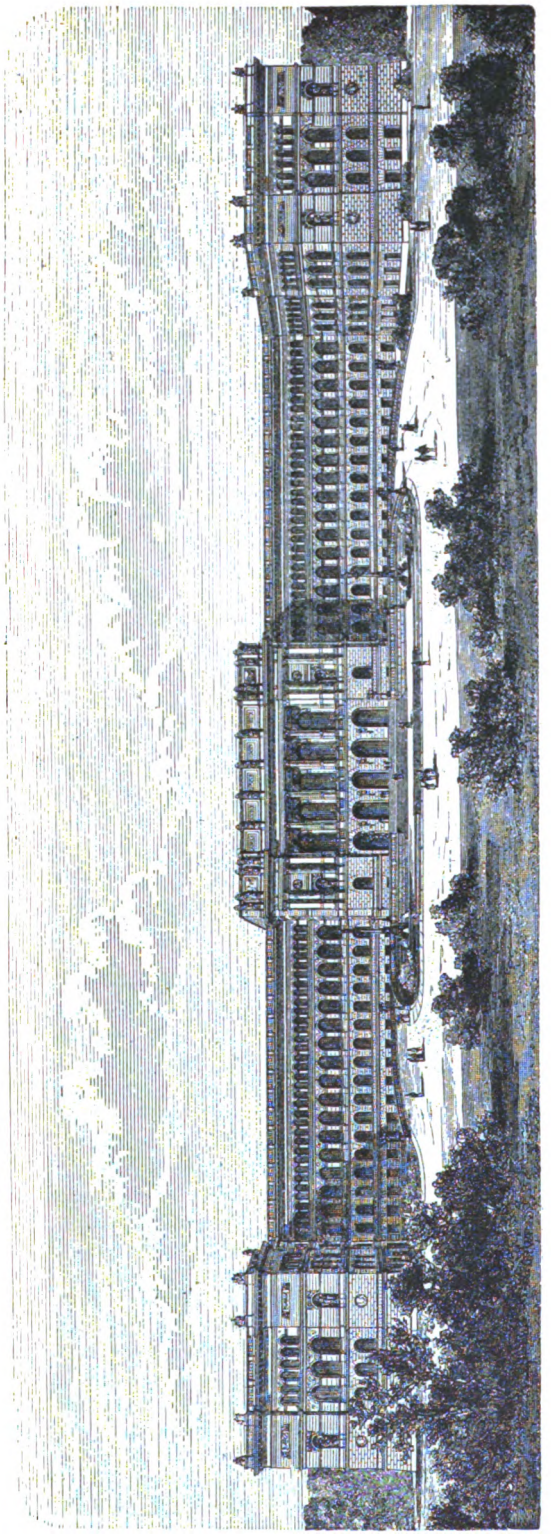

Fig. 1.—General View of the Front of the Main Building.

As will be seen from the plan, Figure 2, the structure is built round five courts, each about 75 feet square. The central court is covered with a handsome glass roof, and the floor is raised sufficiently high above the ground to obtain room beneath for the ventilating and heating apparatus. This covered central court forms, in fact, the large central hall of the building. It is handsomely treated and decorated, and is surrounded with wide galleries on each floor, access to which is obtained by artistically arranged stairways. Some idea of this hall and its decoration can be obtained from Figure 4, which is a view along the main corridor. The main entrance, which is to the left of the corridor, leads into a hall, on either side of which is a departmental museum, to be mentioned more particularly later. The steps at the end of the hall lead into the main corridor, across which is the spacious central hall, a corner of which can be seen on the right of the corridor. No description can adequately convey to a reader the sense of artistic environment which this hall creates. The glimpses of the stairways and galleries seen through the double-columned arches surrounding the hall afford, from every point of view, a most pleasing architectural perspective.

The remaining four courts were originally left open for the access of light and air, but recently the two outer ones have been covered with a glass roof in order to obtain additional accommodation. As the plans and figures show, the lecture rooms and the various departmental offices are distributed to the right and left of the main hall. The corridors run on the inside of the building, getting air and light from the open courts. The main lecture rooms are in the parts of the building separating the courts from one another, this arrangement allowing entrance to be made to them from both the north and south corridors. The small lecture-rooms and class-rooms run round the outside of the building on all four stories.

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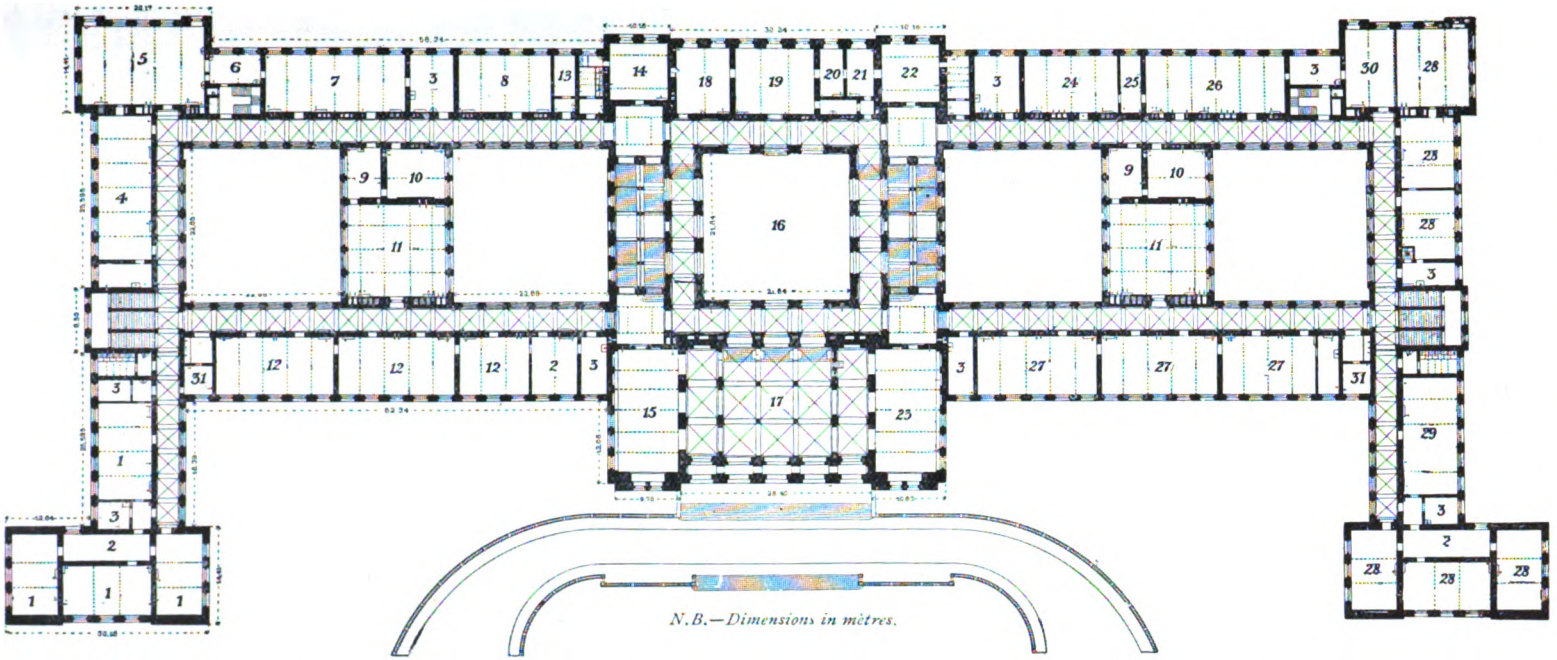
FIG. 2.—GROUND PLAN OF THE ORIGINAL BUILDING.



1. Class Rooms, Architecture.
2. Plan Room.
3. Professors' Rooms.
4. Museum of Building Models.
5. Small Lecture Room, Physics.
6. Preparation Room.
7. Collection of Physical Apparatus.
8. Callenbach Collection.
9. Toilette.
10, 11. Lecture Rooms.
12. Class Rooms, Building Construction.
14, 18, 19, 20, 21. Offices connected with the Administration.
22. Rector's Room.
17. Entrance Hall.
15. Museum.
16. Central Hall.
23. Museum of Engineering Models.
24. Museum of Machine Elements.
25. Assistants' Room.
26. Collection of Kinematic Models.
27. Class Rooms, Drawing.
28. Class Rooms, Engineering Department.
29. Collection of Machine Models.
30. Collection of Apparatus.
31. Attendant's Room.

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Figure 3 is a view of the east wing and shows the general character of the external treatment more in detail.

The work of the school is organised into the six following departments:—

1. Architecture.
2. Civil Engineering.
3. Mechanical Engineering, including Electrical Engineering.
4. Naval Architecture and Marine Engineering.
5. Chemistry and Metallurgy.
6. General Science.

A certain number of the professors belonging to each department constitute the "college" of the department. The "college" elects two of their number to the Senate. The Senate thus consists of twelve members, two from each department. The professors from all the departments yearly elect a "rector," who is the educational head of the school. The organisation therefore consists of, firstly, "Rektor and Senate," the Senate being composed of professors, two from each department. Then six departments, each being organised in the same way, with a number of professors, one being the head of the department, and each having a "college," composed of certain professors, whose functions are elective.

FIG. 3.—ROYAL TECHNICAL HIGH SCHOOL, CHARLOTTENBURG. VIEW OF EAST ELEVATION.
From a Photograph.

Each department is complete in itself. Lectures are given by a large staff of professors appointed by the Culture Minister, and one of the professors acts as the head of the department (Vorsteher). There are, in addition, a number of assistants, styled Privat-Dozenten, who take regular lecture courses, and also a number of honorary assistants. For instance, in the Civil Engineering Department there are eighteen professors, seventeen private "dozenten," and fifty-three honorary assistants, to deal with about 700 students.

In the year 1902-1903 there were 402 members of the teaching staff and 4378 students. Besides this there is an office staff of thirteen, and a library staff of forty-four. These figures give some idea of the enormous educational net spread out in the Berlin Technical High School for the capture of a genius, and show also what a large number of men are educated for industrial pursuits

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in Germany, to a degree far beyond anything that can be done in this country for the average student.

A German student receives his ordinary education in a school of the Gymnasium or the Oberrealschule type. In the first kind in fact has advanced far enough in this branch of study to make it unnecessary for him to take the mathematical course at the Technical High School arranged for students entering from a Gymnasium.

An examination is held at both kinds of

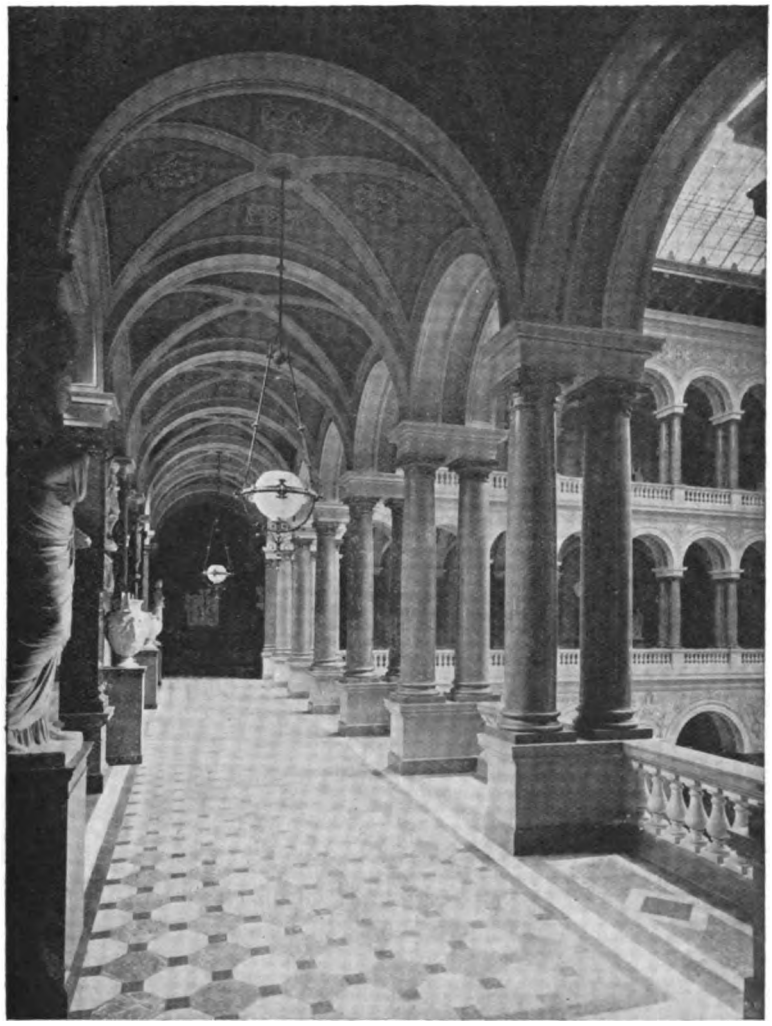

FIG. 4.—THE CORRIDOR ON THE FIRST FLOOR OF THE ROYAL TECHNICAL COLLEGE, CHARLOTTENBURG.
From a Photograph.

the instruction is mainly classical in character, though mathematics forms an essential part of the course. In the second kind, modern languages are more studied than classical ones, and the mathematical work is carried to a higher degree than in the Gymnasium. A student from an Oberrealschule has studied the differential and integral calculuses, and school at the end of six years' study, the passing of which entitles the student to be excused two years of the compulsory military service. A second examination is held three years later, that is, at the end of a nine years' school course, which is known as the Maturity Examination. The certificate of this examination (Reifezeugniss) is accepted in lieu

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of an entrance examination at the High School. Those admitted in this way are called *students*.

Those who have not obtained this certificate are admitted to the school, but form a separate class known as *Hospitanten*.

Foreigners are admitted by special regulation only to the class of *students*.

The Berlin Technical High School has recently been given the status of an university, and *students* may, at the end of their course, obtain a diploma entitling them to be styled "Diploma Engineer," or they may obtain the University degree of "Doctor Engineer." These distinctions are written respectively "Dipl.-Ing" and "Dr.-Ing." These distinctions are granted to all departments alike, so that apparently all branches of applied science are supposed to be some form of engineering.

Hospitanten are not allowed to proceed to a degree, but may obtain a certificate of attendance.

After admission all students spend at least a year in the sixth department, acquiring a sound knowledge of general scientific principles, after which they specialise in one or other of the five branches of technical study provided.

The distribution of students in the various departments of the school is shown by the table on the opposite page.

From this it will be seen that at the present time the Mechanical and Electrical Engineering Department alone has almost as many students as the school was originally designed to accommodate, namely, 2000. Considerable extensions have therefore been, and are being made, to keep pace with the growing numbers of students attending the school.

THE CHEMICAL LABORATORY, CHARLOTTENBURG.

From a Photograph.

Another feature that cannot fail to strike those interested in shipbuilding is that there are nearly 400 students in the naval department of the school.

It cannot be too often impressed on the reader that the 4378 students of the Berlin School are all over eighteen years of age; they have all received an education before they enter the school far in advance of anything that is given in the secondary schools

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of this country, and that they are taking a day course of study lasting for four years.

The table below shows the distribution of teaching staff between the different Departments.

In a subsequent article the course of study will be examined more particularly, in order that a comparison may be instituted between what is understood by a technical training in Germany and in England.

TABLE SHOWING THE STUDENTS AND TEACHING STAFF IN THE VARIOUS DEPARTMENTS.

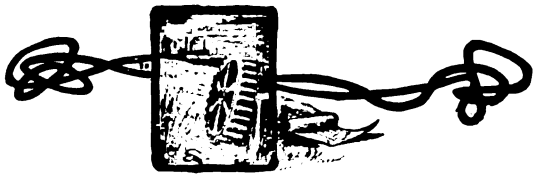
STUDENTS, HOSPITANTEN, AND OTHERS (HEARERS), IN ATTENDANCE FOR THE WINTER HALF-YEAR, 1902–3.

	Students.	Hospitanten.	Total.
1. Architecture	477	262	739
2. Civil Engineering	647	42	689
3. Mechanical Engineering:			
Specialising in Mechanical Engineering	1319	180	1499
Specialising in Electrical Engineering	270	51	321
4. Naval Architecture:			
Specialising in Naval Architecture	241	18	259
Specialising in Marine Engineering	106	17	123
5. Chemistry and Metallurgy:			
Specialising in Chemistry	161	20	181
,, ,, Metallurgy	169	11	180
6. General Science	6	—	6
Persons admitted under special regulations from affiliated Institutions	—	—	80
Officers and Engineers from the Navy	—	—	301
Total	3396	601	4378

TEACHING STAFF.

	Architecture.	Civil Engineering.	Mechanical Engineering.	Naval Architecture.	Chemistry.	Science.
Professors	18	14	20	6	13	18
Priv. Dozenten	17	8	8	1	17	15
Construction Engineers	—	—	7	2	—	—
Lecturers	—	—	—	—	—	2
Assistants	1	1	13	3	15	4
Honorary Assistants	53	33	67	9	10	27
Total	89	56	115	21	55	66

Total Teaching Staff	402
Office Staff	13
Library Staff	44
Attendants	8
Total	467



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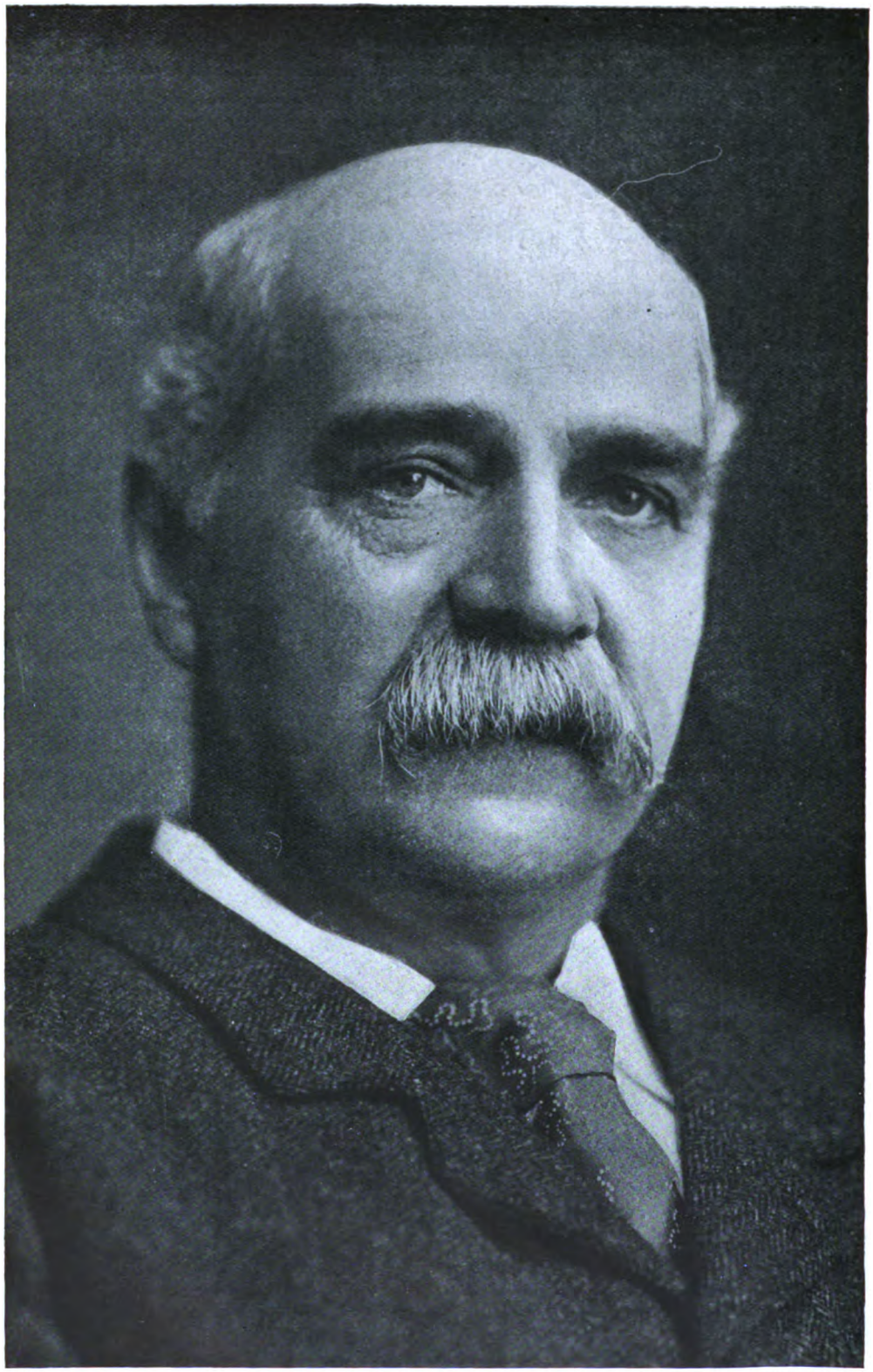

Photo by *George Newnes, Ltd.*

SIR WILLIAM DE W. ABNEY, K.C.B., D.Sc., D.C.L., F.R.S.

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A RETROSPECTIVE GLANCE AT TECHNICAL EDUCATION.

By Sir WILLIAM de W. ABNEY, K.C.B., D.Sc., D.C.L., F.R.S.

T is interesting to take a retrospective glance at the progress that Technical Education has made during the last fifteen years, as it is helpful in making a forecast as to its future development. It is no fiction to say that in the small hours of a morning in the Parliamentary session of 1891 a resolution was carried in the House of Commons, which has had a greater impression on our national prosperity than could ever have been prophesied. The resolution diverted the residue of the money given to localities under the Customs and Excise Act from becoming a fund to compensate publicans and allowed its application to Technical Instruction, or to the relief of rates, at the option of the local authority. This option made it not only possible but certain that it would be largely devoted to the encouragement of that form of education the necessity of which was beginning to be strongly felt in the country. In 1889 Sir W. Hart Dyke had introduced and passed a Bill empowering local authorities to raise a rate in aid of Technical Instruction, in which was included Technological, Agricultural and Commercial Instruction, and the funds coming from the Customs and Excise Act if devoted to Technical Instruction need to be applied on that Act. Little was done to put the Technical Instruction Act in force, the enthusiasm of the authorities being damped by the fact that to do so necessitated local burdens being increased—always an unpopular step in all localities. It is a question whether the Act indeed would not have become a dead letter to all intents and purposes, as so many other Acts have become which involve the voluntary raising of a rate, had it not been that the passing of the Customs and Excise Act removed this dread of unpopularity and placed in the hands of the local authorities a sum of about £780,000, now near a million, or an equivalent to a rate of 1d. in the £, which was authorised by the Technical Instruction Act. It is because this large sum was available that the success in the spread of Technical Education is due, and it is in this sense that passing of the resolution was almost an epoch-marking event.

Customs and Excise Act

As the residue of the money (after payment of Police Pensions) could be devoted to the purposes of the Act, the local authorities were not, as a rule, averse to allowing those who had taken a real interest in the cause of education to cause a part or the whole of it to be devoted to Technical Instruction. Nothing came out of the pockets of the localities by ear-marking the money—which came as a gift—for such a purpose, and, on the whole, the schemes were popular.

Attitude of Local Authorities

A minority, however, of the local authorities decided to apply this residue to the relief of the rates—a minority which has practically disappeared, for the example of other authorities, and the palpable benefits which time showed were bestowed on the population where technical education was being carried out gradually reduced it, till, in 1902, it may be said that the application of the whiskey money to education became universal in England.

During the first few years it must be admitted that the grant was spent unwisely in some instances, but it has to be remembered that the local organisations for directing the new educational movement were incomplete, and the men who had educational fads had their way for a time. Common sense, particularly where efficient directors or secretaries to the Technical Instruction Committees had been appointed, eventually prevailed, and the expenditure was confined to the encouragement of those branches of instruction which were most suited to "the circumstances of the different localities."

Help from the Science and Art Department

It was fortunate for these authorities that they had a central authority, the late Science and Art Department, from whom in the first instance they could seek advice. The advice given always included amongst the objects to be aided Technical Institutes and the Science and Art classes already in existence, together with the establishment of such institutions and classes where none existed, but appeared necessary.

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How largely this advice was followed may be judged from the annual Parliamentary return made by localities of the expenditure of the whiskey money. To anyone not conversant with all the details of the movement it may seem incredible that in the one item of "Technical Institutes" the increase has been from 27 to about 400 at the present time.

It may be safely said that it would have been impossible for the Technical Instruction Act to have passed when it did, had it not been for the preliminary work which the Science and Art Department had done during the preceding forty years. This Department, the creation of which was largely due to the initiative of the late Prince Consort, commenced its missionary work of teaching Science in 1853, when the first Science classes were established. These were evening classes for the instruction of artizans in subjects which were of direct use in their daily life. It must be admitted that at first the artizans by no means appreciated the blessings which it was the wish of the State to bestow upon them, as they suspected that they would interfere with their Trade Unions, and their suspicions went so far as to cause students who attended the evening classes to be treated with active hostility. In 1863, however, the country was roused to the probable decline in trade by the want of Technical Education, and the crusade which was carried on in favour of such education in all parts of the country, converted active opponents into earnest supporters of the movement. From that time the number of classes and students increased, until, from a paltry few thousands being spent by the State on their support, we find that in the last Estimates some £400,000 was voted by Parliament for this purpose.

Decline of Trade and Technical Education

The Report of the Royal Commission in 1889 on Technical Instruction fanned the flame which was already burning, and indicated what further developments were required. The Society of Arts had been one of the earliest agencies in the promotion of Technical Education by the establishment of examinations in technological subjects or the application of Science and Art to industry. These examinations they handed over to the City and Guilds of London, whose subjects of examination now comprise most of the trade subjects of the country. It was the preliminary work carried on by the Science and Art Department, followed by the activity of the City and Guilds of London, that led to the passing of the Technical Instruction Act, to be followed a little later by the passing of the "Customs and Excise" Act. The recent Education Act has made it compulsory on the authorities to devote all the whiskey money to Technical and Secondary Education, and by it they are also empowered to raise a rate for the same purpose. The localities have in some instances sanctioned such rates by not protesting, and it is probable that the whiskey money will soon be largely supplemented throughout the country by the same means. The reorganization of the evening classes which were formerly held under the elementary branch of the Board of Education will all prove of the greatest benefit to the spread of Technical Instruction. The greater freedom in earning the grants from the State for organised Science Instruction in institutions where higher Technical Instruction is also carried out, as shown in the last regulations of the Board of Education, will also give a great impetus to the establishment of instruction suitable for the higher walks of industry. With these signs of activity before us, and taking into account the rapid strides that have been made in educating the people as to the education required, it is not too much to hope that another decade will show us such an advance in instruction in all subjects which are connected with trade, as will enable us to compete with foreign countries on more favourable terms than we have done in recent years.

Re-organisation of Evening Classes

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METALLOGRAPHY; OR, THE INTERNAL STRUCTURE OF METALS.

By A. H. HIORNS, Director, Metallurgy Department, Birmingham Municipal Technical School.

THE study of the internal structure of metals has received an immense impetus of late years from the application of the microscope to the examination of polished and etched specimens, which reveals the more intricate and ofttimes extremely minute variations in their internal architecture. It must not, however, be imagined that there is an essential difference between the microstructure and the ordinary structure, for there is only one structure in a given metal, although as a rule it is necessary to use a microscope to get the constituents sufficiently magnified for the eye to be able to perceive them. In many cases the structure is large enough to be seen with the naked eye, as in the case of the metals zinc and tin, and when this is not the case a pocket lens will often be found sufficient for the purpose. The use of the microscope in its application to metallurgy was first mentioned in 1722 by Réaumur, who described the structure of a chilled casting, and traced the changes in the structure of softened cast iron as modified by the elimination of impurities. François again, in 1833, took the very interesting case of the direct reduction of iron from its ores, and followed the successive changes by the aid of the microscope. The following passage is full of interest, and might have been written by a worker of the present day. "If to these analytical data observations under the microscope, with a magnification of 300 to 400 diameters, be added, it is seen that ordinary iron is merely a metallic network with a close-grained tissue and submerged scoriaceous opaline, sometimes subcrystalline portions, with little globules and metallic grains arranged in every direction; sometimes nests of translucent prismatic and bacillary crystals, with metallic portions adhering, are noticed hidden in the paste; these are grains of steel which can be made to disappear by heating."

In 1864 a fresh impulse was given to metallography by the labours of Dr. Sorby, in whose admirable work polished and etched specimens of iron and steel were employed.

FIG. 1.—MICROSTRUCTURE: ALLOY, 76% LEAD, 14% TIN, 10% ANTIMONY.

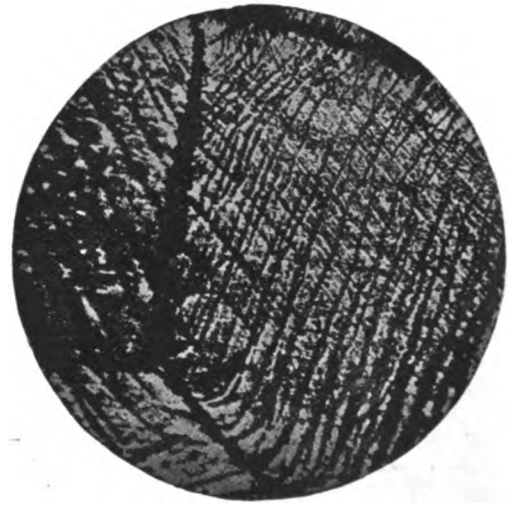

FIG. 2.—MICROSTRUCTURE: SOFT IRON WITH CRYSTALS OF FERRITE.

The same procedure is now followed, and the key-note of the whole science is, to use Dr. Sorby's words, that "steel must be regarded as an artificial crystallised rock, and to get a complete knowledge of it must be regarded as such." Other workers, notably

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FIG. 3.—MICROSTRUCTURE: GRANITE.

Osmond and Werth in France, soon began to recognise the immense possibilities of this method, and devoted close attention to it with characteristic thoroughness and energy. In 1883, we find a paper on the subject contributed by Mr. J. C. Bayles, in America, followed by one by Mr. F. Lynwood Garrison in 1885. In the same year Dr. Wedding read a paper, on the microstructure of iron and steel, to the members of the Iron and Steel Institute. A few years later those indefatigable workers, Messrs. Arnold, Stead, Howe, and Martens, entered the arena, and have since then contributed voluminous reports to various societies and journals on this fascinating and highly useful subject. Among other active workers may be mentioned Messrs. Andrews, Behrens, Chatelier, Sauveur, and a host of others. This application of the microscope has proven so advantageous that it is now becoming a necessary adjunct of every up-to-date laboratory. Until recently, the applications of the metals to the arts and sciences have been based almost wholly on the results of chemical analyses and certain mechanical tests involving breaking strength and limit of elasticity. But chemical analysis can only partially determine the constitution and physical properties of complex bodies; it can take no account of the mechanical treatment the metal has undergone in the process of manufacture. Hammering, rolling, squeezing, drawing, annealing, etc., induce changes of structure which profoundly modify the elasticity and other physical properties, though they do not in the least change the ultimate chemical composition. The effects of impact, torsion, alternations of stress, and excessive strain, can only be fully appreciated when the changes of structure induced in the metals affected are fully known. In such cases the application of the microscope renders a most valuable aid in elucidating the source of these changes, inasmuch as it reveals to the eye the altered configuration of the constituent bodies.

The most important results of the microscopic investigation of metals have been obtained from the study of alloys for their physical constitution, which has an intimate connection with their physical properties. The alloy at present claiming chief attention is steel, with its great variety of structures, differing not only with each content of carbon, but also with that of other constituents, either adventitious or purposely added to produce a given effect. That the nature and arrangement of structure is by far the most important factor in determining physical

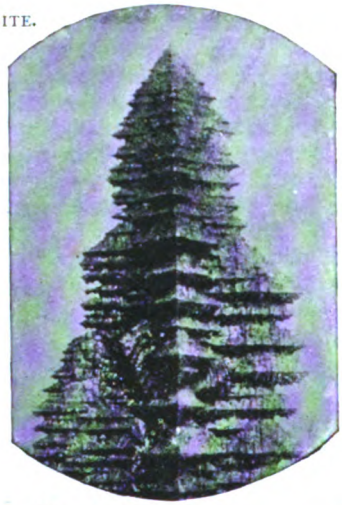

FIG. 4.—PHOTOGRAPH: IRON CRYSTALS.

FIG. 5.—PHOTOGRAPH: TIN CRYSTALS IN TIN PLATE.

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FIG 6.-- PHOTOMICROGRAPH : CRYSTAL GRAINS, CAST SILVER.

properties is becoming more evident every day, and most of the researches of metallographists are conducted on this assumption, for it certainly enables one to explain many problems otherwise insoluble, such as the cause of cracks, breakages, and other defects in samples of similar chemical composition.

Another illustration may be taken from the case of bearing metals, used for reducing friction. These alloys are found to consist of different constituents varying in hardness, and the load of the journal is carried through them by the hard component of the alloy, which is found to possess a low coefficient of friction, the plasticity of the matrix making it possible for the bearing to adjust itself closely around the shaft. The plasticity may be ascertained by means of a compression test, but the nature of the constituents must be determined by microscopical examination. On polishing such alloys on a yielding support, the softer portions are dug out, while the hard parts stand in relief; bearing alloys, therefore, have a structure which is made apparent by the polishing process. Fig. 1 is an alloy of 76 per cent. of lead, 14 of tin, and 10 of antimony. The tin is a constituent of the hard grains, diminishing their hardness, and also their brittleness: it also enters into the composition of the eutectic alloy, increasing its compressive strength.

The question of the "form of the component bodies" in metals, as to whether they are true crystals, or amorphous grains, or exist as an intermediate state which may be expressed by the term "crystal grains," is a debatable point. Mr. H. M. Howe, in *The Metallographist* of January 1902, asks the question, "Should external form, or the polarised organisation of matter of which that form is only the most striking manifestation, be taken as the essence of crystalhood?" Mr. Osmond considers that the term crystal must depend on external form, so that the fact that the matter of which the object is composed is polarised around certain axes, while essential to crystallography, does not itself constitute crystallography, but that the external form must be geometrical, and a function of the internal arrangement.

Now it is quite essential that metallographists should come to some decision as to the exact phraseology to be used to express those individual entities which, while they rarely have a geometrical exterior, have most of the other characteristics of true crystals. The standard dictionary defines a crystal as "a chemically homogeneous body which, in the absence of external or internal stress, is anisotropic, and possesses the property of growing in a supersaturated solution." If, then, the body is of definite composition, and anisotropic, that is, having different properties along lines of different directions, it is essentially a crystal, or at least a crystal-grain. Such a body, for example, is ferrite or pure iron, which is known to have cleavage planes in certain directions, and is capable of growing in a solid solution. Fig. 2 is soft iron with crystals of ferrite, showing slips along the cleavage planes, due to pressure. Fig. 3 is a section of granite showing similar cleavage planes in the mica. With regard to the

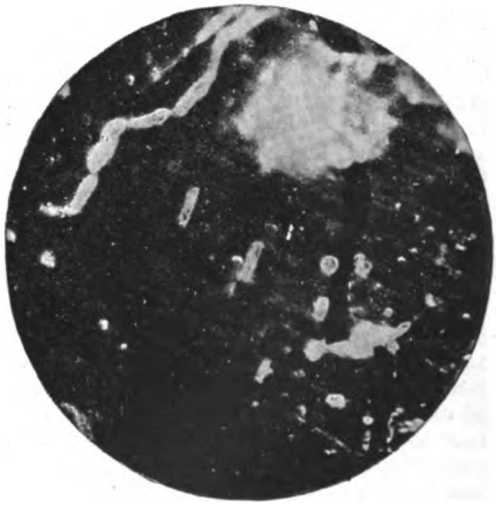

FIG. 7.—"SLIP-BAND": STRAINED IRON.

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crystalline structure of metals, Mr. Stead remarks, that granules and crystals should not be confused together, for if they are not of geometrical external form, but take their form from their surroundings, they cannot be crystals.

FIG. 8.—MILD STEEL AFTER ANNEALING AT 700° C.

It is therefore better, in cases where the form is not definite, to call such bodies crystal grains. But the tendency is to shorten such compound words, and if the term "grain" or "crystal" is used alone, it is generally understood to refer to those constituent bodies of alloys, which, though deformed and imperfect, are still in their essence crystalline. The manner in which crystalline structure is developed varies, but the main factor is temperature. It is a well-recognised fact, that the more slowly a metal is cooled from the freezing point, the larger will be the dimensions of the crystals, the more perfectly will they be formed, and the more symmetrically will they arrange themselves with regard to each other. On the other hand, if a metal be submitted to pressure, not only will the individual crystals be distorted, but the orderly arrangement of the whole mass will be disturbed, and when the pressure is carried to a certain extent the metal will become so weak as to be easily fractured by a slight additional force. Now as the crystalline condition is the natural state of a metal, any deviation from this will be unnatural. In that case the molecules are ever tending to pass back again to the normal state, which is perfectly effected by remelting, and in a great measure by annealing. Fig. 4 is a photograph of iron crystals. Fig. 5 is a photograph of tin crystals on tinplate. Fig. 6 is a photomicrograph showing the crystal grains of silver, taken from cast silver, in the natural state, without any preparation.

Messrs. Ewing and Rosenhaim have shown that when a piece of iron, for example, is strained in tension, its crystal grains become elongated in the direction of tension, but when the specimen has been subsequently annealed by being heated to a bright red heat, all signs of elongation disappear from the crystalline pattern revealed by the microscope, and the metal has resumed its original condition. The same gentlemen have found by the investigation of metals under strain, that when the metal is stretched beyond its elastic limit sharp black lines appear on the surfaces of the crystals, parallel to each other in each crystal, but in different directions in different crystals. They then look like a crevassed glacier and the lines like cracks. These lines are not cracks, but "slips" along the

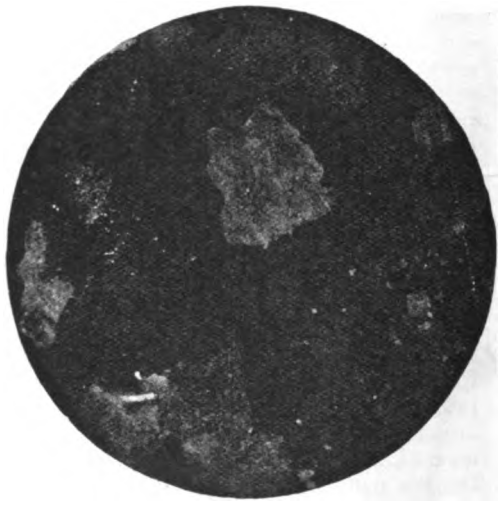

FIG. 9.—PHOTOGRAPH: CAST LEAD COOLED SLOWLY.

cleavage or gliding planes, and are termed "slip-bands." Such bands are also produced by compression or torsion, and it is in virtue of this action that plasticity in metals is possible. Fig. 7 shows slip-bands with sliding just starting. The same phenomenon is seen well developed in Fig. 2, after Ewing and Rosenhaim.

Messrs. Arnold and Stead have demonstrated that prolonged annealing tends to produce large crystals in iron and steel, but even a short exposure to a suitable temperature produces complete recrystallisation.

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Fig. 8 represents mild steel after being subjected to a prolonged annealing at 700° Centigrade. It has been suggested that these changes take place at critical temperatures corresponding to the "arrest points" in the cooling of the metal, and indicate evolutions of heat. It is therefore natural to suppose that they are evidences of rearrangement of structure. In some metals, such as lead, mechanical treatment seems to have no permanent influence on the shape of the crystals, for if sheet lead, which has necessarily been subjected to a very great amount of plastic deformation, is etched with dilute nitric acid and examined under the microscope with reflected oblique light, it is seen to be highly crystalline. The crystals have many straight lines meeting at sharp angles, several sets of parallel boundaries being frequently observable. The effect is due to the repeated occurrence of twin crystals. If lead is cast and allowed to cool very slowly, especially if it be

FIG. 10.—PHOTOMICROGRAPH: EUTECTIC MIXTURE OF STEEL.

kept a long time just below its melting point, large crystals are developed, which are revealed very brightly after etching with dilute nitric acid. Fig. 9 is a photograph from a cake of lead which has been so treated.

An impure metal or alloy is not generally a simple mixture of the metals, but the constituents enter into solution or chemical combination to form a number of distinct bodies which conjointly form the alloy, giving it its particular structure, and collectively determining its properties. We may thus consider the following cases:—1. Free metals in a pure

FIG. 11.—PHOTOMICROGRAPH: EUTECTIC ALLOY, SILVER 66%, ANTIMONY 34%.

state. 2. Solid solution of one metal in another. 3. Solid solution of one metal in the allotropic modification of another. 4. Chemical compounds in an excess of metal. 5. Solid solution of definite chemical compounds in each other. 6. Eutectic mixtures.

It will be seen from the above how complicated an alloy may be, what a great variety of modifications are possible, and how complicated the structure may be. To simplify the explanation we may consider the cases of a metal existing as an alloy in the free state, or as a chemical compound, or as a solution of one or both of the above, each constituent body having its own melting point and other characteristics, but modified by the associations in which it exists. In the simplest form we have two components in such proportions as to be chemically united, yielding a uniform non-crystalline structure like glass, or in such proportions as to be mechanically mixed without combination or separation, forming what is termed an "eutectic alloy," often having a more or less striated appearance, but of practically uniform structure throughout the mass. Either a pure metal, or a chemical compound, or a mechanical mixture, may separately exist in the general mass of an alloy. The mechanical mixture may be simply two metals, or a metal and a chemical compound; in either case it generally has a lower melting point than the metal in which it is diffused, and is therefore the eutectic or alloy of minimum fusion. If therefore

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an alloy consists of a metal and a eutectic, the former, on cooling, will solidify first, leaving the eutectic in the liquid condition, much in the same way as a salt, in crystallising from a liquid solution, leaves behind a mass of mother liquor. The eutectic of an alloy is the mother liquor of a solid solution, and therefore forms the matrix or groundwork from which the other constituent has solidified. Fig. 10 is a photomicrograph of steel containing 0·89 per cent. of carbon, which is the eutectic mixture of steel. Fig. 11 is a photomicrograph of an alloy of 66 per cent. silver and 34 per cent. antimony, the striated portion representing the eutectic alloy. Fig. 12 is a photomicrograph showing crystals of the chemical compound Al_2Cu, in a eutectic matrix.

For the exact examination of the structure of metals, it is necessary to have the specimen perfectly flat and free from scratches, as the latter tend to mask the real structure; further, flatness enables all parts to be properly focussed under the microscope, an indispensable condition when photography is used. The section, for convenience, should be about half an inch square and one-eighth of an inch thick. It may be mounted, for final examination, on a glass slide with Canada balsam, plasticine, wax, or other suitable adhesive material, or it may be soldered on to a piece of flat metal. The first process is to rub it smooth and flat on a dead smooth file, and afterwards remove the scratches with emery and rouge. Different grades of emery-paper can be purchased, marked O, OO, OOO, and OOOO respectively. Each grade should be mounted on a smooth block, and the specimen rubbed on each one in turn, care being taken to rub at right angles to the former rubbing, so as to obliterate the previous marks completely. The final polishing is done on a skin of chamois leather, coated with the finest jewellers' rouge. When a large number of sections have to be prepared, a polishing machine, driven by power and arranged to take four revolving bobs, is a great advantage. These consist of a fine emery wheel, a disk covered with canvas for use with fine flour emery, a third covered with cloth on which is used alum and Castile soap, and a fourth covered with chamois leather and rouge.

FIG. 12.—MICROPHOTOGRAPH: CHEMICAL COMPOUND Al_2Cu.

The etching liquids used for steel are: dilute nitric acid, tincture of iodine, infusion of liquorice, ammonium nitrate, etc. For copper and brass: dilute nitric acid, hydrochloric acid, and ammonia are suitable. For alloys with much zinc, potash is the best re-agent. In fact, a great number of different liquids are available for the purpose.

When a complex body is polished on a yielding base, the different constituents are worn away unequally, and the harder parts stand out in relief, as in Fig. 1. In some alloys the constituents may be revealed by polishing on a wet cloth, so that the liquid used may, by the friction, exert a slight chemical action on the structure.

Etching polished metals with corrosive liquids is sometimes liable to lead to confusion of the crystalline structures. With feeble etching the constituents may be rendered visible; with strong etching the granular and often the crystalline bodies are developed, but another method, termed "heat tinting," is very useful in revealing differences of structure. The metal is heated on a plate till the temperature is sufficient to produce oxidation films, differing in colour on the different constituents. This method has the advantage over etching that none of the metal is dissolved and the surface remains flat.

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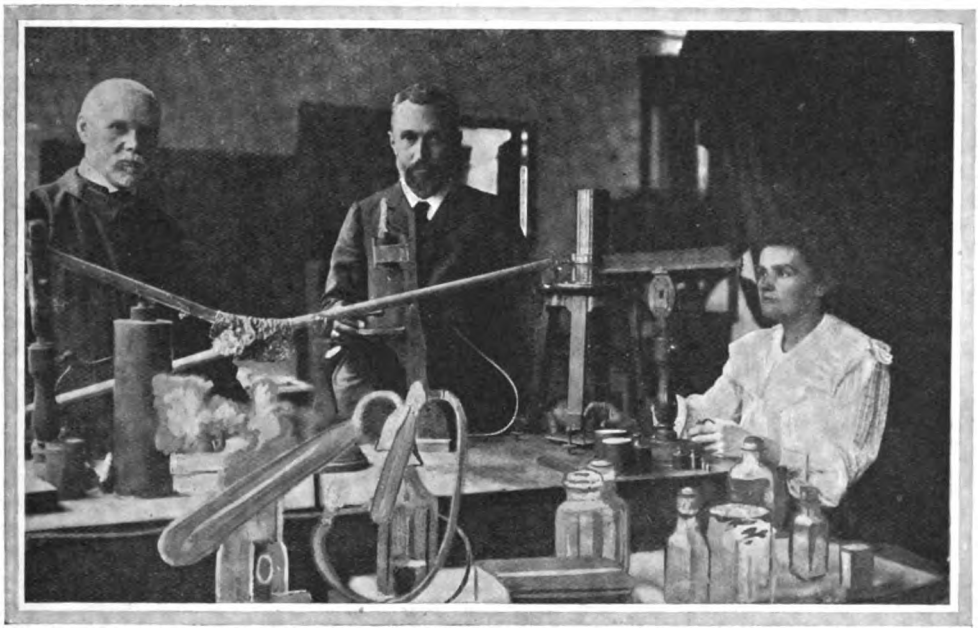
RADIUM.

By EDWIN EDSER, A.R.C.S., F.Ph.S., Head of the Physics Department, Goldsmiths' Institute.



From a PROFESSOR AND MADAME CURIE AT WORK ON RADIUM. *Photograph.*

(The middle figure is Prof. Curie.)

NEW discoveries have ever excited so much interest as that of radium and its congeners. Nevertheless, a sample of radium presents to the eye no very remarkable peculiarity. A number of small crystals, or perhaps a whitish powder, contained in a small glass tube—that is all one sees. In the dark the crystals glow with a faint phosphorescent light, no more striking, however, than that often emitted by decaying fish. Thus to a casual observer a sample of radium might appear of no more interest than a small fragment of phosphorus. To the scientist, however, radium appears as the most remarkable of the many elements with which research has made us acquainted. Some of its properties are of so unprecedented a character that a profound modification of our scientific theories is rendered inevitable; others throw light on phenomena which have previously presented difficulties, or confirm daring speculations; and finally, certain of its properties may in the near future be turned to practical account in the service of man. Many of these properties have been revealed by methods of research which have taxed the ingenuity and skill of our greatest investigators; the discoveries made are the direct outcome of a long series of arduous investigations, carried out by scientists of various nationalities, along lines which, though widely separated, are now seen to converge to most unexpected meeting points. From this it follows that, before the peculiarities of radium can be understood and appreciated, a certain amount of preliminary scientific training is necessary. It speaks well for our national education that radium has excited a far keener interest in England than on the Continent; while it is a subject for further congratulation that many important discoveries have been made by our own countrymen.

X Rays

In 1895 Professor Röntgen discovered the remarkable rays which he termed "X Rays," but which are now often spoken of as "Röntgen Rays." These rays, in common with ordinary light, possess the property of travelling in straight lines, and can therefore cast well-defined shadows. Unlike light rays, they have no direct effect

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on the eye; they can, moreover, traverse many substances, such as wood and flesh, which are opaque to light. The less dense metals, such as aluminium, are fairly transparent to X rays, while a thin sheet of a dense metal, such as lead, is practically opaque to them.

Professor Röntgen's discovery set many investigators to work in attempts to discover other forms of radiation more or less similar to X rays. It had long been known that sulphide of zinc, after exposure to sunlight, continues for a time to emit light in a dark room. In 1896 M. Henry found that, besides the light which is visible to the eye, the sulphide emits non-luminous rays which can traverse several layers of black paper, and subsequently affect a photographic plate. This discovery was followed up by Professor Henri Becquerel, who found that the double sulphate of uranium and potassium acts in a similar manner. At first Becquerel supposed that the rays capable of penetrating paper were only produced when the uranium salt had been exposed to sunlight. A happy chance, however, convinced him of his error. A photographic plate had been covered, in a dark room, by a number of layers of paper, and some of the uranium salt had been scattered over this, with the intention of exposing it to sunlight. The weather was, however, cloudy, and the shielded plate covered with the salt was placed in a drawer, where it remained in the dark for some weeks. At the end of that time it was decided to develop the plate; it was found that the plate was darkened under each patch of salt, so that the latter must have been emitting radiations which were independent of exposure to sunlight. Subsequent researches proved that uranium continues to emit these radiations years after exposure to light; what is still more significant, a uranium salt which has been dissolved and allowed to crystallise out in the dark, was found to be equally active. The rays discovered by Becquerel can traverse wood and the less dense metals. Fig. 1 is reproduced from a radiograph of an aluminium medal obtained by Professor Becquerel in 1896. The aluminium medal was laid on a photographic plate, after which some double sulphate of uranium and potassium, which had never been exposed to light, was spread on a sheet of card placed above it. It will be noticed that the thicker parts of the medal were more opaque to the emitted radiations than the thinner parts.

Becquerel Rays

PROF. HENRI BECQUEREL.
From a Photograph.

Professor Becquerel also found that the rays which he had discovered convert air through which they pass into a conductor of electricity. Thus a fragment of uranium salt placed near a charged electroscope causes the leaves of the latter to rapidly fall together. X rays have a similar property.

Sir William Crookes effected the next important step in advance. He found that the radiation proceeded, not from the uranium itself, but from some then unknown impurity. He determined this by a process of fractionation, in which, starting from a uranium salt, he obtained two products, one of which was radio-active, while the other was not.

At this point the subject was taken up by Professor Pierre Curie and Madame Sklodowskà Curie. To understand the advance effected by their investigations, it must be mentioned that uranium is mostly extracted from a mineral termed pitchblende, which contains 81½ per cent. of uranium, 4 per cent. of lead, ½ per cent. of iron, together with small quantities of barium and several other known elements. Professor and Madame Curie first found that the activity of a mineral containing uranium was not proportional to the amount of uranium present; some minerals were much more active than pure uranium. The radio-activity was tested by the capacity of a sample to discharge an electrified body placed near it. Next the uranium was separated from the pitchblende, and its activity tested; it was found to be less active than the residue, which was, therefore, assumed to contain some unknown radio-active element. From the residue one known substance after another was isolated, the activity of each being carefully compared with that of the remainder. This method led to the discovery of three strongly active elements present in pitchblende: polonium, actinium, and radium. Of these, radium is by far the most active. Its chemical properties approximate to those of barium, from which it can be separated by fractionation, the chloride of radium being less soluble in water, alcohol, or hydrochloric acid, than the corresponding salt of barium.

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This method is an excessively tedious one, and is rendered more tedious still by the small amount of radium present. It will be remembered that the greater proportion of pitchblende consists of uranium; about 7,000 tons of the residue obtained after removing the uranium would suffice to produce about 2 lbs. of radium. After enormous labour extending over two years, Professor Curie has succeeded in treating about eight tons of uranium residues, and has obtained about a gram of fairly pure radium chloride—about enough of the crystallised salt to fill an ordinary salt spoon. In Germany there is now possibly a gram of radium chloride, while all other countries, exclusive of France, possess less than half a gram. If made by present methods, a pound of radium would cost about £200,000.

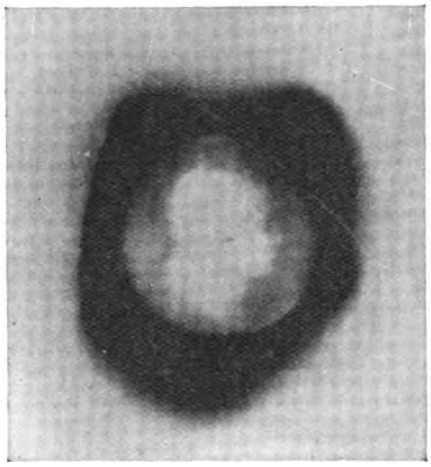

FIG. 1.—RADIOGRAPH OF AN ALUMINIUM MEDAL PRODUCED BY BECQUEREL RAYS.

The spectrum of radium has been examined by Demarcay, who finds that it possesses a number of characteristic lines not to be found in the spectra of other elements.

Professor and Madame Curie have determined the atomic weight of radium, and find it to be equal to 225. Runge and Precht, from considerations based on the spectrum of radium, estimate the atomic weight to be 257·8.

Radium is probably a metallic element, but it has not been isolated in the metallic form. It is at present known only as a chloride or bromide.

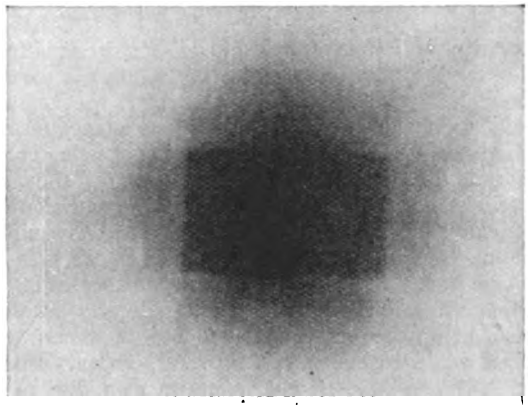

FIG. 2.—RADIOGRAPH, PRODUCED BY RADIO-ACTIVE LEAD.

The question may now be asked, What is the reason that radium has excited so much interest, and why are eminent men content to devote so much time and labour to its production and examination? It is not merely that radium is a new element: the seventy odd elements known twenty years ago have been increased to some hundreds, and yet small excitement has been caused, except in the case of the new gases found in the atmosphere; one element more or less is now a matter of small importance. The answer is, that radium possesses properties heretofore unknown, which would certainly have been considered impossible a few years ago. In the first place, radium continually emits light without any apparent change in its physical or chemical constitution. When a piece of phosphorus emits light in a dark room it is accounted for by the fact that a slow combustion is taking place; after a limited time the phosphorus burns itself out, when its luminosity ceases. Balmain's luminous paint glows in a dark room, but then it must have been previously exposed to sunlight, and after a time its luminosity dies out; the energy absorbed from the sunlight is slowly given out in the dark, till the store is exhausted. The luminosity of decaying fish, and that sometimes observed in the sea, is due to lowly organisms, and ceases when these organisms die or are deprived of oxygen. But, like Tennyson's brook, the luminosity of radium, so far as we know, goes on for ever.

Light is a form of energy, and for a substance to continually emit light without drawing on any store of energy, is as much in contravention of our accepted ideas as for a steam-engine to work without a constant supply of coal.

But this is by no means the end of the

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matter. Lately, M. Curie has found that radium continually emits heat. A small quantity of radium, when placed in an enclosure kept at a constant temperature, maintains itself constantly at about 1·5° Centigrade above the temperature of its surroundings. Each gram of radium emits enough heat to melt its own weight of ice per hour. Here again we have an emission of energy without any apparent source of supply. The striking nature of this discovery may perhaps be made clearer by another statement. If 14 lbs. of radium could be procured, and all the energy given off as heat could be utilised mechanically, then it would suffice to drive a one horse-power engine for at least 50,000 years. So far as direct experiments are concerned, it might drive the engine eternally, since no evidence has been obtained of any loss of weight in the radium; but Rutherford calculates, on certain assumptions, that a gram of radium *may* decrease in weight by about one part in fifty thousand per year.

This opens up an interesting field for speculation. One point which has been a source of much difficulty to scientists is that, assuming the sun to be merely a heated body, it cannot continue to give off heat for more than a few million years; while the earth cannot have been cooling down to its present temperature for a period so long as that indicated by a study of geological formations. If, however, radium occurs in the sun, the latter may possess an enormous store of energy heretofore undreamed of. Mr. Wilson calculates that 3·6 grams of radium to each square metre of the sun's surface would suffice to supply all the heat which the sun radiates. Similarly, if radium exists in any amount in the interior of the earth, it would account for the earth's internal heat.

Radium not only glows in the dark, but it also renders bodies placed near it temporarily self-luminous. The hands and clothes of an experimenter who has been handling radium glow with a phosphorescent light, which continues for a considerable time after the radium has been stored away. The explanation of this is, that the radium gives off an *emanation* which is self-luminous.

FIG. 3.—BECQUEREL'S METHOD OF SHOWING THE MAGNETIC DEVIATION OF β RAYS.

If some radium is enclosed in a glass vessel, connected with another vessel by means of a tube provided with a stop-cock, then a faint nebulous light is seen to proceed from all parts of the vessel containing the radium, but if the stop-cock has been kept closed, no light is emitted from the interior of the other vessel. When the stop-cock is opened, the glow is seen to slowly creep along the connecting tube, and in time to fill the second vessel. If the second vessel consists of two bulbs connected by a tube, then the glowing emanation may be condensed in the lower one by plunging the latter into liquid air; thus the emanation consists of a gas-like substance, which can be condensed, like an ordinary gas, by extreme cold. Rutherford has estimated the "atomic weight" of the emanation by observing its rate of diffusion from one vessel to another, and finds that it is equal to about 100. The emanation is not, therefore, vaporised radium, but is a substance of lower atomic weight.

It appears that it is the emanation, and not radium itself, which is self-luminous. If radium is heated the emanation is at first given off profusely, but at a red heat no more appears to be evolved. On cooling the radium, its luminosity is found to be lost, but is recovered after a few days' rest. Thus the emanation appears to be a gas-like substance formed from the radium; it is capable of being condensed on surrounding objects or on the radium itself. Heating drives the emanation off, and after cooling, a definite time is required before a new supply can be produced. It has been found that the atoms or particles of which the emanation is composed carry positive electric charges.

A recent experiment, due to Professor Schuster, appears to show that the heating effect is also due to the emanation. One junction of a thermo-couple was placed in a vessel traversed by a stream of air charged with radium emanation. The junction was maintained for a considerable time at a very low negative potential. By this means the positively charged emanation was condensed on the junction. The junction was then removed, and placed in a vessel kept at a constant temperature; the other junction was

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placed in a similar vessel kept at the same temperature. In the circuit of the thermo-couple was included a galvanometer, which of course showed no deflection so long as both junctions remained at the same temperature. After a short time, however, a deflection of the galvanometer indicated a rise of temperature in the junction, which was coated with the condensed radium emanation. This enhanced temperature was maintained for some time, about so long, in fact, as a substance which has been exposed to the emanation takes to lose its luminosity.

In addition to the light and the emanation given off by radium, there are several kinds of non-luminous radiations emitted. These radiations are somewhat similar to those first observed by Becquerel, but they are much more intense. They all possess the property of discharging electrified bodies on which they fall, and they are all capable of traversing substances which are quite opaque to light, and subsequently affecting a photographic plate.

Not only is radium itself capable of emitting these radiations, but a substance which has been placed near to it also acquires this property. Fig. 2, due to Professor Becquerel, was obtained by placing a piece of lead, which had been previously exposed to the emanation from radium, on an opaque sheet which covered a photographic plate. The plate was blackened under the lead, showing that the latter emitted radiations which could traverse a sheet opaque to ordinary light.

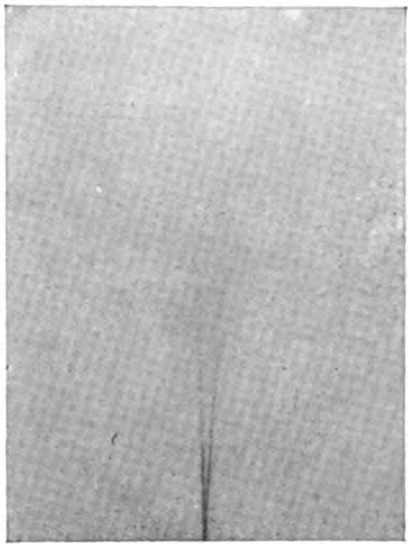

FIG. 4.—BECQUEREL'S METHOD OF SHOWING THE MAGNETIC DEVIATION OF α RAYS.

Much of our present knowledge of the non-luminous radiations emitted by radium and substances in which radio-activity has been induced by exposure to radium emanations, is due to Professor Rutherford. He has found that a considerable proportion of the radiations emitted cannot traverse a thin sheet of aluminium; those radiations which have not been stopped are capable of traversing a much thicker sheet of the same material without sensible loss, showing that the radiations are of different kinds. The first thin sheet stops the less penetrative rays, and allows the more penetrative rays to proceed. He termed the less penetrative radiations α rays; those which have greater penetrative capacity he termed β rays. A layer of air a few millimetres thick is practically opaque to the α rays, but is transparent to the β rays.

Both the α and β rays convert air through which they pass into a conductor of electricity. Professor and Madame Curie have further shown that the β rays carry negative charges of electricity, which they impart to bodies on which they fall. If the β rays fall on a body surrounded by air, the body does not become charged, since the air itself is rendered conductive by the rays, and the charge leaks away as quickly as it is formed. When, however, the rays fall on a body enclosed by a vessel in which a high vacuum is maintained, the body becomes negatively charged, and a constant stream of negative electricity can be obtained from it.

Another distinction can be drawn between the α and β rays. It is well known that when an electrical conductor carries a current at right angles to the lines of force of a magnet, the conductor is acted upon by a force which will displace it, if it is free to move, in a direction perpendicular to itself and to the lines of force. It is this force which produces the rotation of the armature of an electro-motor. Rowland showed that a stream of electrified particles is equivalent to a flexible conductor carrying an electric current, and is deflected in a magnetic field just as the conductor would be. Becquerel found that the β rays are deflected when they pass at right angles to the lines of force of a powerful magnet, thus giving confirmatory evidence that the β rays consist of streams of charged particles.

Fig. 3 will explain an experiment due to Becquerel. Imagine a rectangular block of lead, with a deep vertical saw cut in one of its sides, to be placed on a photographic plate. Let a small quantity of radium be placed at the bottom of the saw cut; then

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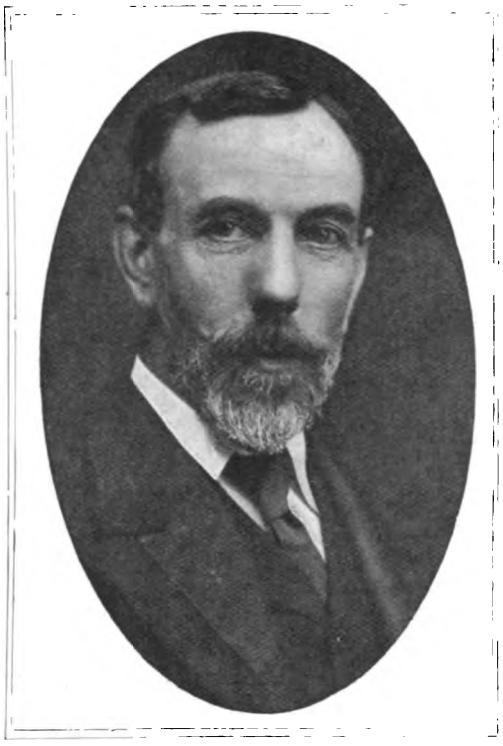
the only radiations which can fall on the plate are those which have travelled from the radium through the orifice of the saw cut. These radiations will affect only a narrow strip of the photographic plate, lying directly in front of the saw cut; just as light which has traversed a deep and narrow slit would do. Now imagine the whole of the above arrangement to be placed on a pole of a strong magnet. The lines of force will proceed vertically upwards through the plate, and the radiations will cut these lines at right angles. Those rays which consist of charged particles moving with a considerable velocity will be deflected to one side and form a dark brush on the developed plate, inclined to the dark strip produced by the undeflected rays. This result is shown in Fig. 3. The central dark strip with sharply defined edges is due to the undeviated α rays, while the dark brush on the right-hand side is due to the β rays which have been deviated by the magnetic field. The direction of deviation proves that the β rays consist of negatively charged particles. Becquerel has found that these particles travel with a considerable velocity, equal, in fact, to about one-third of the velocity of light. It further appears that the mass of each particle is equal to about the one-thousandth part of the mass of a hydrogen atom.



SIR WILLIAM RAMSAY.
Photo by Elliott and Fry. Copyright.

A study of the α rays presents difficulties of a character much more serious than those encountered in the study of the β rays. As already remarked, a layer of air a few centimetres thick is practically opaque to the α rays; thus the nature of these rays can only be investigated at points near to the radiating substance. It was at first thought that the α rays were absolutely undeviable; but Professor Rutherford found that, in a very strong magnetic field, a small deviation can be observed. This result has been confirmed by Becquerel, using a method depending essentially on the following principle. A block of lead, with a vertical saw cut containing radium in its depths, is placed, as before, on a photographic plate. When this arrangement is supported on the pole of an exceedingly strong magnet, the readily deviable β rays are deflected through a considerable angle, on one side or the other of their undeviated direction. Thus if a sheet of lead is placed a few millimetres from the block, with a narrow vertical slit directly in front of the saw cut, then none but the α rays will be able to pass through this slit, the β rays being deflected on to the lead on one side of it. By this means the α rays are isolated. Becquerel found that the α rays, after passing through the slit, are slightly deflected when the field is very strong. If the magnet is strongly excited by a current which is reversed after a suitable interval of time, then the α rays are deflected first toward one side and then toward the other, and two narrow streaks appear on the developed plate (Fig. 4). The direction in which the α rays are deflected shows that these rays carry positive electric charges. Professor Rutherford has calculated that the particles composing the α rays each possess a mass equal to twice that of a hydrogen atom; their velocity is very high, amounting to about twenty million metres per second.

Sir William Crookes has invented a simple contrivance termed the *spinthariscope*, by which the effects of the α ray particles can be observed in a most striking manner. A small fragment of radium is placed directly in front of a screen coated with powdered zinc blende (sulphide of zinc). On observing

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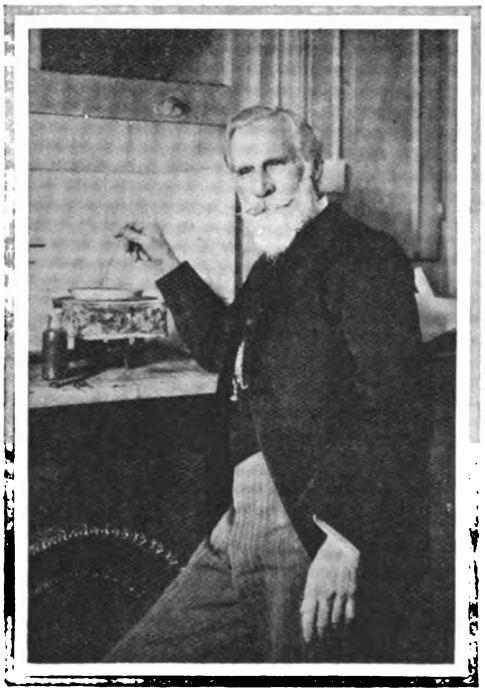
this screen in the dark through a lens, scintillating points of light continually flash into view and die away. Each scintillation is supposed to be produced by the impact of a single α ray particle. This experiment stands absolutely alone in showing the effects of isolated bodies of atomic dimensions.

Of the radiations emitted by radium, a small proportion possesses much greater penetrative power than either the α or the β rays. These exceedingly penetrative rays are termed γ rays. They are undeviable by a magnet, and apparently carry no electric charge. It is probable that they are essentially similar to X rays.

To summarise the results already described. Radium emits an emanation, which is a gas-like substance incapable of passing through even the thinnest layer of mica, metal, or paper. This emanation affects substances exposed to it, and causes them to become self-luminous and radio-active. The luminosity and radio-activity of radium itself is probably due to the emanation entangled among its particles. Radium, or a substance which has been excited into radio-activity by means of the radium emanation, emits three kinds of non-luminous rays. The α rays are very slightly penetrative, are only deviable by the very strongest magnetic fields, and carry positive charges. The particles composing the α rays have masses equal to twice that of a hydrogen atom, and travel with a velocity of twenty million metres per second, or 2×10^9 cms. per second. The β rays are much more penetrative than the α rays, they are readily deviable by a magnetic field, and carry negative charges. The particles composing the β rays have masses equal to about one-thousandth part of the mass of a hydrogen atom, and travel with a velocity of about one hundred million metres per second, or 1×10^{10} cms. per second. The γ rays do not consist of charged particles, and are much more penetrative than the α or β rays. They are probably closely allied to, if not identical with, X rays.



SIR WILLIAM CROOKES.
Photo by George Newnes, Ltd.

Within the last year our knowledge of radium radiations has been increased in a most surprising manner. Rutherford and Soddy were the first experimenters to show that the radium emanation could be condensed at the temperature of liquid air. The same experimenters pointed out that minerals containing uranium and radium are almost universally found to possess helium occluded in their pores; it was suggested, might not helium be one of the products of disintegration of the helium emanation? Sir William Ramsay and Mr. Soddy extracted the gases occluded in 20 milligrammes of radium bromide, and from these removed oxygen and hydrogen by chemical means. The residual gas was found to contain carbon-dioxide, and this was frozen out with liquid air. The remaining part of the emanation, which had not been removed along with the carbon-dioxide, was then examined spectroscopically, and was found to give the well-known line D_3 of helium.

Now this helium was certainly not present in the freshly-prepared radium bromide, and as helium does not occur in the atmosphere, it could not have been absorbed subsequently. There appears to be no alternative to the conclusion that *radium itself changes into helium*. Of course, if this is possible, then the dream of the alchemists, the transmutation of metals, may also be possible. It should be noticed that radium is one of the elements possessing a high atomic weight, while helium is an element possessing a very low atomic weight. It has long been considered possible by many scientists, notably by Sir William Crookes, Sir Joseph

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Norman Lockyer and Prof. J. J. Thomson, that all elements are built up out of some primordial substance, probably existing in the form of excessively minute particles. Here at last we have experimental foundation for such a belief.

Briefly, then, our present knowledge leads us to the following theory, due to Professor Rutherford. The element radium consists of heavy and complicated atoms, which spontaneously break up into simpler atoms. The "emanation" is perhaps the first product of this atomic break-down, and a further disintegration produces still simpler elements, among which is helium. It is

PROFESSOR J. J. THOMSON.

From a photograph.

probable that the α ray particles are positively charged helium atoms. Among the disintegration products are particles much smaller even than atoms; these particles, carrying negative charges, constitute the β rays. The impact of the β rays on surrounding objects, or on the helium itself, produces X rays, which in this case are termed γ rays. In a similar manner the streams of negatively-charged particles projected from the kathode of a vacuum tube give rise to the X rays discovered by Röntgen. Since the above process liberates an enormous amount of energy, the radium atom must contain stored energy of considerable amount.

Our chief difficulty is to know *why* the radium atom disintegrates. Of course it is known that the atoms and molecules of a substance are in motion among themselves, and it occurs to one that the disintegration may be due to the shocks of violent atomic collisions. Although this hypothesis appears to be the most reasonable we might adopt, it is not in the least supported by experimental evidence. When a substance is heated, its molecules are set in more active motion, and their collisions are more violent and more frequent; but when radium is heated the chief effect appears to be that the emanation already formed is driven off; there is no conclusive evidence of greater disintegration occurring at high than at low temperatures. Professor Dewar has cooled radium down to the temperature of liquid hydrogen, that is, to a temperature only a few degrees above the absolute zero; at this temperature radium is, if anything, *more active* than at ordinary temperatures.

A few words may be said as to the possible applications of radium. In the first place the radiations from radium appear to possess the property of disintegrating organic tissues. While journeying to London to give a lecture, Professor Becquerel carried a small sample of radium, enclosed in a sealed glass tube, in his waistcoat pocket; subsequently an ugly sore developed in the flesh which had been nearest to the tube. Professor Curie states that if a pound of radium could be procured he would be afraid to go into a room with it; he is of opinion that he would become blinded and paralyzed in a short time. A small fragment of radium introduced beneath the skin of a mouse, near the spinal column, produced speedy death from paralysis. Nevertheless radium may prove to be a most valuable aid in surgical operations of which the aim is to destroy foreign or injurious growths. Thus it has been suggested that a small sealed tube containing radium should be introduced into the midst of deep-seated cancers, with the object of destroying the cancerous growths. Professor Rutherford suggests that the inhalation of air, which has bubbled through water containing a radio-active substance, may prove effectual in curing consumption. Professor Ramsay suggests that the Bath waters, which are known to contain helium, and to lose their efficacy by standing, may owe their medicinal properties to small quantities of radio-active substances present in them.

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DR. WALMSLEY'S TOUR IN AMERICA.

A MOST important departure in connection with technical education was decided on by the Governing body of the Northampton Institute, Clerkenwell, early in 1903. Much has been said and written about the superior methods of tuition in vogue abroad; nevertheless, there is little trustworthy information to hand on this important topic, since in many cases a generous appreciation of the progress observable in foreign countries has been palpably combined with but a scanty knowledge of the state of education in this country. When, however, the McGill University of Montreal, and the Massachusetts Institute of Technology, are found to be holding matriculation examinations in London, presumably in the hope of attracting students from this country, it would appear to be time to ascertain the advantages which these and other foreign institutions can boast of. It was accordingly decided that Dr. Walmsley, Principal of the Northampton Institute, should spend three months in America, in a tour of inspection of American educational institutions. Dr. Walmsley left England on March 7th, 1903, and returned to London on June 9th.

STARTING from New York, Dr. Walmsley proceeded south through Philadelphia and Washington, then westwards to Pittsburgh and through Ohio, Indiana, Illinois and Wisconsin to Milwaukee and Chicago, whence turning eastwards he proceeded by way of Michigan and Niagara Falls to the northern parts of New York State, and after going northwards to Canada, New York was again reached on the return journey through the New England States. In this itinerary thirty-four of the most important educational institutions in America were visited. Moreover, Dr. Walmsley interviewed seventy-seven employers, manufacturers, and professional men, in addition to the teachers in the institutions visited. Since returning to England, Dr. Walmsley has issued a preliminary report on his tour, and by his courtesy we are enabled to refer to the chief points thereof.

American Students

The inquiry was chiefly directed toward the higher engineering education, and consequently the students chiefly referred to are those who enter the engineering faculty of a university, or the day classes of a technical institute, with a view to graduating as engineers. It appears that the right of granting the degree M.E. or E.E., or their equivalent, is not confined, in the United States, to universities, but may be legally conferred by many institutions, some of which are not of university rank. Those students whose aim is to rise from the bench to the positions of "gang bosses" and "foremen" in the factories, are dealt with in a separate section.

The students who aim at graduating as engineers are drawn chiefly from youths who have passed through the "High School," or its equivalent. The general plan of education is, that a boy enters the primary school at the age of six; after spending four years there, he proceeds to the grammar school, where he spends another four years. At fourteen, those who can afford to do so pass into the High School or the Manual Training School. In the High School the training has a classical and literary bias; in the Manual Training School the bias is scientific and practical. At eighteen, the student, if he can afford to do so, enters a University or technical college, in order to complete his training in a further four years' course.

Many educationalists hold that the literary training of the grammar school affords a better groundwork for engineering students than can be obtained at the manual training schools. It appears that, in many of the latter institutions, there is a tendency to attempt too much in the way of scientific and technical instruction, with the result that elementary education is neglected in favour of superficial scientific acquirements.

Dr. Walmsley concludes that, in America, students taking up a collegiate engineering training (1) can be counted in hundreds, as compared with tens or less in this country; (2) they enter college at a later period of life; and (3) are better prepared for their subsequent work.

Curricula.

In general, the first two years of a student's life at an American University or Technical Institute are devoted to a general scientific training in mathematics, chemistry, and physics; sometimes English and foreign languages are included. In many instances a considerable amount of time is devoted to workshop

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practice. In the last two years of his training the student is introduced to a host of professional subjects, with the not infrequent result of imperfect assimilation.

In the Engineering School of the McGill University and the Toronto School of Practical Science, the curricula much more nearly follow English practice.

Buildings and Equipment

These are notably better than are generally found in this country. In each technical institute visited there was at least one large building devoted exclusively to engineering studies. In many instances, in addition to a building as large as the largest London polytechnic, the engineering section possessed two or more buildings for special purposes, such as laboratories and workshops. Most of these buildings have been erected in the last ten years. It may, perhaps, be urged that the equipment in America is too lavish, and that much of the money spent on palatial buildings might have been better spent on more utilitarian purposes. This latter criticism was made by more than one native critic interviewed. The fact remains, however, that in his third and fourth years the student handles machinery and apparatus of the latest and most up-to-date pattern, and of a size adequate to elucidate principles and solve problems on an engineering scale.

Fees and Living Expenses

College fees range from £7 to £50 per annum, but in most of the State colleges inhabitants of the State are admitted free, or only have to pay a nominal sum for materials and incidental expenses. Many colleges are non-residential. The cost of living, for students residing near the college, ranges from £28 to £100 per session in country districts, and from £45 to £180 in the large cities.

The College Staffs

The provision of a suitable staff for engineering colleges has been found to present great difficulties. Each member of the staff is required to have had commercial experience in the branch which he is called upon to teach, and in addition it is highly desirable that he should be a trained teacher. These two conditions are often found to be incompatible. Consequently, men possessing the necessary qualifications can demand and obtain high salaries. In State colleges, professors are not merely permitted to do outside work, but are required to do so, in order that they may keep themselves abreast of the various lines of progress in their profession.

In spite of the high salaries at present paid many keen business men are in favour of a material advance in this respect. One manager of a large engineering works, himself a college graduate, with over ten years of added practical business experience, went so far as to say that he would not care if the whole of the equipment were scrapped, if by so doing the salaries of the teachers could be substantially increased, with a view to getting the most capable engineers to take up the work.

Post-Graduate Work

Most colleges and schools offer inducements to capable students to spend one or more years in post-graduate work, either immediately after graduating, or after a period spent in outside work. Some institutions have been established merely for post-graduate work, and two of these—the Johns Hopkins University in Baltimore and the Clark University in Worcester, Mass.—were visited. Both of these institutions are splendidly equipped, and the results of researches carried out by students are considered to have amply repaid the outlay and cost of maintenance. In both these cases it has been found necessary to supply preliminary training of an undergraduate character.

The Proof of the Pudding

Between 1890 and 1901 the sum of 23 millions sterling has been devoted by American citizens to the cause of technical education; in addition to this, large sums of money have been voted by the States for the same purpose. The question arises, has this money been well spent? In other words, has the scheme, briefly explained above, proved successful in turning out capable engineers? The answer to this question may be found in the fact, that many employers not only favour the appointment of men possessing graduate certificates from an Engineering University or Technical School, but some go further, and accept as apprentices for their technical staffs only those who possess this qualification. It is now becoming customary to seek out the most promising graduates before they have completed their courses. Some firms enter into negotiations with the college authorities as early as April, for the purpose of securing the men who are expected to graduate in June.

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Subsequent Career of Students.

In America all employers offer to graduates a living wage at the start, and *do not charge any premium.* In fact, the premium apprentice appears to be unknown in America. Graduates are willing to start low down, because they know that they will have a fair field for their advancement. It is asserted that outside influence, whether exerted by large shareholders in important companies, or by others, is not permitted to push forward less competent men to the detriment of their more competent fellows. In most cases, at the end of six months a college graduate advances to a fairly well-paid position, and at the end of two years such men frequently attain to responsible and lucrative posts.

The Training of Bench Hands.

The methods in use to obtain a sufficient supply of skilled workmen for large factories were found to vary greatly in different branches of engineering work, and in different parts of the country. Some firms possess a regular system of apprenticeship, whilst others trust to chance to supply the men they require. For many years the stream of skilled immigrants from Europe has tended to mitigate the difficulties which might otherwise have been felt in the absence of a supply of trained native labour. At present, however, great difficulties are being experienced, and many firms are actively engaged in drafting schemes of apprenticeship.

In some firms carefully thought out schemes of training are in operation. A member of the staff is often appointed to train the boys, who go through definite courses of instruction in the various shops, and are sometimes required, but more often merely encouraged, to attend evening classes. It appears, however, that in America evening class work is in a much less advanced state than in England; evening schools do not appear to "catch hold," though this is probably due more to defects in the classes themselves than to absence of desire for instruction. Where good evening classes exist they are well patronised.

Comments

Such is the gist of Dr. Walmsley's preliminary report, for which all engaged in furthering the cause of technical instruction must feel grateful. This affords a rare instance of a well-qualified teacher being deputed by the authorities of his institution to pay a prolonged visit to a foreign country, in order to obtain information as to the educational systems at work there.

It is by no means necessary, and it would probably be very unwise, for us to slavishly copy any system of education, however successful it may have proved abroad. Some points are, however, undoubtedly worthy of emulation. The abolition of premium apprenticeship, and the grant of a free field for his abilities to each of the hands of firm, would unquestionably stimulate the desire for instruction in the working classes. To a certain extent working men may, and frequently do, obtain pecuniary profit from technical instruction gained at night schools. But their possibilities of advance are limited, for they soon reach a point where further promotion would place them in positions destined for "gentlemen apprentices." Hence, though elementary classes in the London Polytechnics are well attended, advanced classes are often disproportionately small.

A good point in the American system is the requirement of a thorough scientific grounding in technical students. For an electrical engineer to be competent without a sound knowledge of electricity is as impossible as it would be for a surgeon to be competent without a knowledge of anatomy. Whether it is wise to postpone the study of the technical applications of science to the last two years of a student's training may reasonably be questioned; the most interesting and instructive problems in pure science are often to be found in its technical applications.

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EAST LONDON TECHNICAL COLLEGE AT THE PEOPLE'S PALACE.

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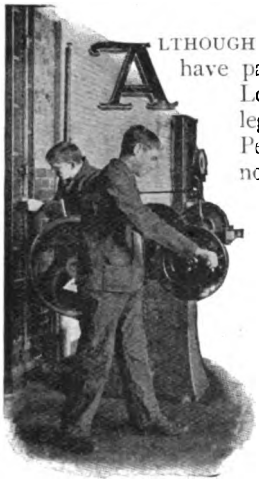
EAST LONDON TECHNICAL COLLEGE.

By J. L. S. HATTON, M.A., Director of Studies, East London Technical College.



ALTHOUGH hardly fifteen years have passed since the East London Technical College was founded at the People's Palace, it is now among the best known of the technical institutions in London. It owes its origin almost entirely to the generosity of the Drapers' Company, who, when the Queen's Hall was opened at the People's Palace, built and maintained a technical school in connection therewith. In the first instance a day school was founded, and evening classes in a variety of subjects were started. Gradually, under the guidance of the Drapers' Company, the college has developed into its present form, the work being modified to meet the changing requirements of the neighbourhood.

The area that it draws students from is large. It extends from Aldgate on the west to Ilford and Leytonstone on the east; from Hackney on the north to the districts on the south side of the River Thames. Pupils even attend from Battersea, Wandsworth, Gospel Oak, Loughton, and Romford, and students have come from South Africa and India to study in its day classes. The district more immediately served by the college contains important chemical and engineering works. Stratford and Silvertown may be considered as the headquarters of chemical industry in London, while the two important engineering firms of the Thames Iron Works and Messrs. Yarrows, Limited, are situated in Poplar, to say nothing of the important locomotive works of the Great Eastern and other railway companies.

The work of the college at the present time is divided under three heads: the evening classes, the day college, and the day school —all under the supervision of a Director of Studies.

The technical day school, which dates from the foundation of the People's Palace, has always been large. It sprang into importance at once through the Drapers' Company awarding annually for many years a hundred scholarships, tenable in it for a period of three years. These scholarships, although small in value, more than covered the expenses of education at the school, and from the first they attracted the best boys leaving the elementary schools. The number of candidates in later years was between five and six hundred. The training in the school has always been of a strictly technical type and in marked contrast to that in schools which, during the last six or seven years, have introduced a certain amount of science into their curriculum. The Governors have always kept in view the fact that most of the boys, leaving the school at sixteen years of age, would be required by circumstances to contribute, at any rate, to their own support. Hence, for those wishing to become engineers a much longer time than is usual is devoted to machine construction and other engineering subjects. As a result of this policy there is a great demand for boys from this school, both for engineering workshops and drawing offices. At the present time it is impossible to supply lads for all the vacancies that occur. The same is the case in regard to chemistry, the applications almost invariably coming through old boys of the school or from their employers. Pupils entering engineering firms or chemical works usually receive on starting wages varying from ten to twenty shillings a week, which, in the case of the ablest boys, are rapidly increased. For a lad entering the engineering profession it is undoubtedly best to commence in a commercial workshop, but many lads from the school, who have started in engineering drawing offices, have afterwards done well. This is doubtless due to the fact that although workshop training in the college is in no wise meant to take the place of apprenticeship, yet, as a matter of fact, the knowledge so acquired is of the greatest assistance to a lad proceeding direct to a drawing office. The training in the school much assists lads to obtain positions in engineering workshops, and employers frequently recommend parents to send their sons to the day school before apprenticing them. Afterwards it often enables them to

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be transferred to the drawing office, whereby they obtain for a very small premium—or none at all—the advantages accorded pupils paying a premium of two or three hundred pounds.

After the college had been started for some years a demand arose for a more extended technical training. It was found, especially in the case of chemical trades, that sixteen was too low a limit of age for pupils to discontinue day study, and although much was done for old boys in the evening classes, progress in these was necessarily slower. Likewise there arose a demand for technical education for boys who had remained till the age of sixteen in ordinary secondary schools. With a view to meet these requirements the Governors, about seven years ago, instituted higher day classes, and the Drapers' Company awarded more valuable scholarships in connection with them. In this way lads of more exceptional ability, from the technical and other schools, were enabled to continue their studies. This branch of the work has steadily increased in importance. In the first instance many students, on reaching the age of eighteen or nineteen, obtained science and mathematical scholarships at Oxford and Cambridge, or proceeded to study chemistry in Germany. Thus sons of the poorest parents have been enabled to obtain the highest possible scientific education.

The development of the college had progressed so far when the London University Commissioners issued their report, in which the heads of the mathematical, physical, chemical, engineering and electrical engineering departments were recognised as teachers of the University, and since that date the scientific and technical teaching of the college has been much developed. In the daytime, and in the evening, students are now prepared not only for the Pass, but likewise for the Honour degrees of the University in many scientific and technical subjects. Valuable scholarships are also awarded by the Drapers' Company in connection with the higher day classes.

The mathematical work is carried on by the Director of Studies, Mr. J. L. S. Hatton, M.A.Oxon., and Mr. W. F. S. Churchill, M.A.Oxon. These gentlemen are delivering honours courses of lectures both in the daytime and in the evening, in connection with London University. Several of their old pupils have had very distinguished careers in mathematics at the University of Oxford. At the East London Technical College great stress is laid on the necessity of both chemists and engineers having a thorough and extended knowledge of mathematics.

The chemistry department has been for many years under the charge of Dr. J. T. Hewitt, M.A.Cantab, D.Sc.Lond., Ph.D. Heidelberg, who till lately was the secretary of the chemical board of studies of London University. The chemical laboratories are large, and have recently been extended and in part refitted. In both manufacturing works and in academic work Dr. Hewitt's pupils have been especially successful. During the last six or seven years many papers embodying the results of original researches have been published from the chemical department of the East London Technical College. Dr. Hewitt is assisted by Dr. Clarence Smith, D.Sc.Lond., and Mr. F. G. Pope, B.Sc.Lond.

Dr. Lehfeldt, B.A.Cantab., D.Sc.Lond., is in charge of the advanced physics work of the college. Much encouragement is given to original research, and students are working under him for the B.Sc. degree in honours and for the D.Sc. The laboratory has recently been extended.

The mechanical engineering department is in charge of Professor D. A. Low, M.I.M.E., who is assisted by Mr. F. G. Castle. The engineering workshops, laboratories, and drawing offices are extensive and well equipped. Special attention is given to laboratory work, and among other machinery available for the use of students is a 50-ton Wicksteed testing machine. Many engineering firms are in the habit of forwarding materials for commercial tests, while in addition to the testing of engines and other laboratory work, students can obtain a valuable experience in fitting and turning. A hopeful sign in regard to the appreciation of technical education by employers is the fact that one of the large railway companies is at present paying the wages of one of its apprentices who is attending the engineering day classes.

New laboratories and workshops have been constructed during the summer for the electrical engineering department, which is under the charge of Professor J. T. Morris. As is only to be expected, this department is exceedingly popular, especially with evening students. The generating station of the college is also available for the use of students, while the dynamo room contains all the newest and most approved appliances. Students of the day classes have left the college to enter many important and well-known firms of electrical engineers.

The evening work has been much modified

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and developed since the institution of the college. As other agencies for evening instruction arose, the policy of the Governors has been to encourage the higher work for the benefit of the serious student, who was willing to make sacrifices to acquire the education necessary to his future advancement. With this object in view, a serious departure from the accepted custom was made by the Governors at the commencement of the session 1902-3. In order to encourage students to take systematic courses of study, the more elementary classes were grouped together into courses, and students were only admitted to these on payment of the fee for the entire courses. This plan has been found to work excellently, and no reduction has been caused in the attendance at the science and technical classes, while the number of serious students has distinctly increased. About twelve hundred (1,200) of such course tickets have already been issued in the present session.

Another important development has been the formation of evening courses for internal students of the University in science and engineering. Evening students wishing to obtain degrees as internal students of the University are placed in a somewhat difficult position on account of the number of hours which they are required to devote to lectures. In spite, however, of these difficulties, eight evening students were last session successful in passing the intermediate as internal students, while three or four others were referred in one subject only, in which they will have to be re-examined. The fact, that the internal degrees of the University of London will offer a guarantee that those who have obtained them have been brought into personal contact with qualified teachers, seems to be fully appreciated by students. In this field of work great developments will probably take place. London University, unlike the older residential universities, has in its immediate neighbourhood an immense population. Scattered among these there is a sprinkling of persons, working for their livelihood in the daytime, who have a real love for science, and many of whom will probably accomplish great things. The day student usually pursues his course of study under his professors for a period of three or four years. At the end of that time the connection is entirely broken, and more often than not his course of study comes to an abrupt conclusion. In the case of the evening student no such climax arises. The relations of lecturer and student continue session after session, and if the courses are properly modified and extended the student may, and does frequently, remain in contact with the same instructor for many years. In this way great things may be accomplished.

At the East London Technical College the numbers attending the engineering subjects are especially large; year after year Whitworth Exhibitions are obtained: in 1903 two students were successful, and in 1902 four. The development of technical education among engineers throughout the country is most unmistakably borne witness to by the increased attainments necessary to obtain these exhibitions.

In chemistry, while the numbers are smaller, the standard of work is high. Physics, excluding the study of electricity, hardly commands the number of students who study chemistry, doubtless because there are not the same commercial openings. The importance of mathematics is now fully realised, and the classes in this subject are large. There are even a few enthusiasts who year after year, for the love of the subject, steadily continue their work in its highest branches. The electrical engineering department is crowded with evening students. To those wishing to become electrical engineers one word of warning should be said. The openings in this direction are not as roseate as is generally supposed, unless the student has a sound knowledge of mechanical engineering.

At the Bow and Bromley branch, which adjoins the North London Railway station at Bow, the Governors have concentrated the classes in more general subjects. There is an excellent biological laboratory, and large classes are held in physiology, botany, hygiene, and kindred sciences. The classes specially intended for women have likewise been transferred to this building, together with those in Civil Service and commercial subjects.

In dealing with technical education certain broad questions arise. It may be asked how far the training in our elementary schools suitably prepares lads for our technical institutions. While elementary education is on the whole good, and the elementary teachers are an enthusiastic and efficient body of men, certain defects in the system are apparent. The dabbling in science in elementary schools, although well intentioned, has not been justified by results. The teaching of such a fundamental subject as arithmetic has deteriorated, and accuracy, which after all is the great pillar on which all science is founded, has suffered. Examinations have

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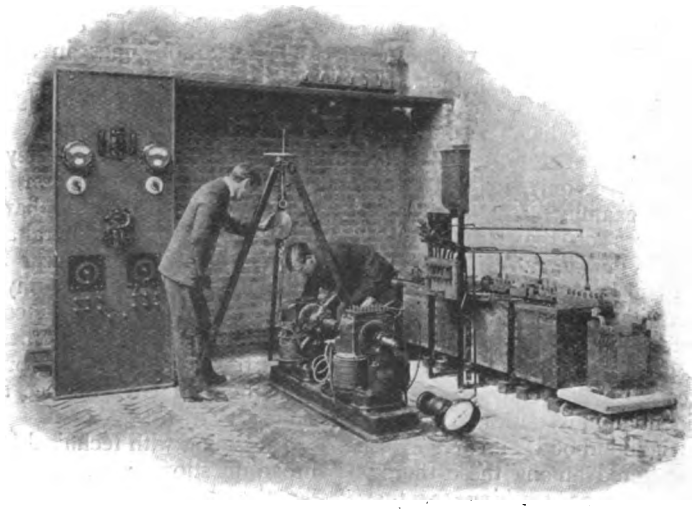
been too far abolished, and boys now pass the sixth and seventh standards who some ten years ago would certainly have been rejected. English composition and spelling are not so good as they should be.

Another serious problem which confronts those responsible for technical education is whether a lad should be apprenticed at sixteen years of age in an engineering workshop, or should continue his studies at a technical college till eighteen or nineteen. The solution of this problem lies practically in the hands of employers. It is at present much easier to apprentice a lad in an engineering firm at sixteen, than to obtain suitable employment for him at nineteen. On the other hand, even if he regularly attends evening classes, the lad who has been apprenticed cannot obtain the same technical knowledge as he would if he continued his studies in a day college. One of the most hopeful signs for the future of engineering in this country is the fact that the most enlightened employers are beginning to realise that it is more to their advantage to receive into their works a highly trained lad of nineteen, than one with practically no training who pays a large premium.

Looking at the question of technical education as a whole, it would seem that great progress has been made, and is being made, to enable the cleverest among our lads, whatever may be their social position, to rise to the highest posts in our manufactories and industries. It is only by completing and perfecting the means for their education that our nation can hope to retain its industrial position.



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PRESENT-DAY MURAL DECORATION.

By ARTHUR SEYMOUR JENNINGS.

Honorary Consultative Examiner in Painters' and Decorators' Work to the City and Guilds of London Institute.

THE public taste in mural decoration fluctuates almost as much, if not so rapidly, as that in ladies' dresses. The requirements of to-day are very different from those of ten years ago, and, no doubt, in another decade other and dissimilar styles will be in vogue. Indeed, the demand for novelty, while not so pronounced in England as it is in some countries abroad—the United States, for example—is very real, so that art students and designers may always be reasonably sure of finding a market for their work, provided, of course, that it is novel and really decorative.

We may leave aside from present consideration those features of modern decoration which have proved to be but short-lived, and direct our attention to the styles which have remained in favour for a long time, or appear to be likely to do so.

Taking wall-papers in their various grades first, the question has often been asked whether the fashion is set by the manufacturers, or whether it is a distinct demand on the part of the public. Probably each contributes to the result. The wall-paper manufacturer who produces a new style, or a series of hangings quite out of the ordinary run, usually "makes haste slowly." The production of a single new design means the risk of not a little money, as the cutting of the blocks or cylinders from which the design is printed is somewhat expensive. For this reason only a few patterns that are distinctly novel are brought out in one season. If they meet with favour—if the sales justify it—the "line" is largely increased the following year.

It is worthy of note that a custom of the wall-paper trade, widely followed, is to reprint a selection of certain designs every thirty years or so. At present there is a demand for pearl, white moiré, and striped papers that were popular in the "sixties."

We may now consider the new styles which are most sold to-day, and first among these must be placed "ingrain" papers, or those which are coloured in the pulp from which

FIG. 1.—A MODERN LANDSCAPE FRIEZE.

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the paper is made. This class of paper is usually either quite plain, or printed with a stripe, or with a small dotted pattern technically known as "powdering." This pattern is almost always printed in the same colour as the ground, but a little darker. Often the difference in tint between ground and pattern is so small that the design can hardly be discerned. The wide use of these plain or nearly plain papers is generally admitted to be one of the best evidences of the process of applied art in mural decoration in recent years.

It may, at first sight, be thought that the use of plain papers does not give much encouragement for the artist. As a matter of fact, however, they are but rarely used, excepting in conjunction with a comparatively bright and often elaborate frieze. The reader who has studied design will be quick to understand why this combination gives such satisfactory results. We will take a well-furnished dining-room as an example. Here we probably have a good many pictures upon the walls, and the plain background, if the proper hue is chosen, forms a setting or foundation for them, which adds to their beauty instead of detracting from it, as is almost invariably the case when a conspicuous pattern is employed. The "powdering" design, so unobtrusive, yet serves to nicely break up those portions of the surface where there are no pictures, while the broad, boldly-drawn frieze, probably full of colouring, gives a fitting cap to the wall surface, and forms a combination effective and decorative. And, be it observed, it hardly matters how strong the colours are in the frieze, because it is above the line of pictures, while the expanse of plain surface will probably require a firm colouring in order to produce a proper balance of parts and a satisfactory whole.

It is in the design of the frieze that the artist will find his greatest opportunities. We do not now refer to the ordinary patterned frieze or border, designed on what Mr. Lewis F. Day calls the "turn-over" principles—that is, of a pattern having its left and right identical—but rather to that class of design which is most sought at the present time. There are two divisions to this class, or perhaps they might be more properly considered quite separately. The first is the "landscape frieze," the second the "hand-stencilled frieze." Both may be recommended to the earnest study of the art student who has reached that satisfactory stage—although so often difficult to get over—of applying knowledge gained in a school of art to the wants of the manufacturer.

FIG. 2.
A HAND-STENCILLED BORDER.

Landscape friezes have made steady progress in favour during the past year or two, and the writer is of opinion that they will continue to be used for some time to come. Provided that they do not become too common, and that the makers do not produce them in very cheap qualities—for it is here the danger lies—there is much to hope from them. A design of this character is shown in Fig. 1, which may be taken as a type, and a very beautiful one, of the class of design now referred to. The best of these decorations are distinguished by a most important feature, which is almost absent from ordinary paper-hangings. *They are adaptable to the length of surface to be decorated.*

The use of all wall-papers, both plain and those executed in relief, is open to the grave objection that, unless great care is exercised in hanging them, the ornament of the pattern will be mutilated. Sometimes this is the fault of the decorator, who has not taken the trouble to centre his pattern even in the case of the mantelpiece, which in most rooms is the most conspicuous feature. But frequently

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the pattern cannot be made to "fit in," and to place one feature of the design in the centre of the mantelpiece only means that a similar ornament would have to be cut at both corners. When a landscape frieze is used the space to be covered must be carefully considered, because the effect would be ruined if part of the design were to be seen "going around the corner," so to speak.

The design shown in Fig. 1, then, is so arranged that portions of the drawing may be left out or added to, as may be desired. If, for example, the length of the room were considerable, and there was no break, two bridges, or even three, might be introduced, while in a smaller space one would suffice. In either case the landscape would be complete. This ingenious arrangement is brought about by certain features, such as the skyline being, in certain places, exactly of the same height, so that part may be cut out as may be desired.

Here, then, is scope for the young designer who wishes to get out of the beaten track. Design a landscape frieze which will look equally well if the room in which it is used is 18 ft. or 25 ft. across. Sometimes the same result is obtained in an entirely different way. The design is so arranged as to consist of half-a-dozen or so definite parts each one separate from the other. When the space is limited these features are brought closer together than before by cutting away portions of the paper intervening.

A very successful method of dealing with this class of design was first brought out some two years ago. This was a seascape executed by hand by means of stencils. The design was simple and consisted mostly of the outlines of vessels of various sizes. In order to cope with the problem of dealing with spaces of different sizes, the artist arranged to omit or add to the number of vessels, and a further difference was made by changing the position of some of the outlines, so that no two lengths of this particular design were exactly alike. The writer believes that in the preparation of wall-paper designs—not only friezes, but side hangings as well—that are adaptable to the size of the particular surface to be covered, there will be the most marked progress during the next few years.

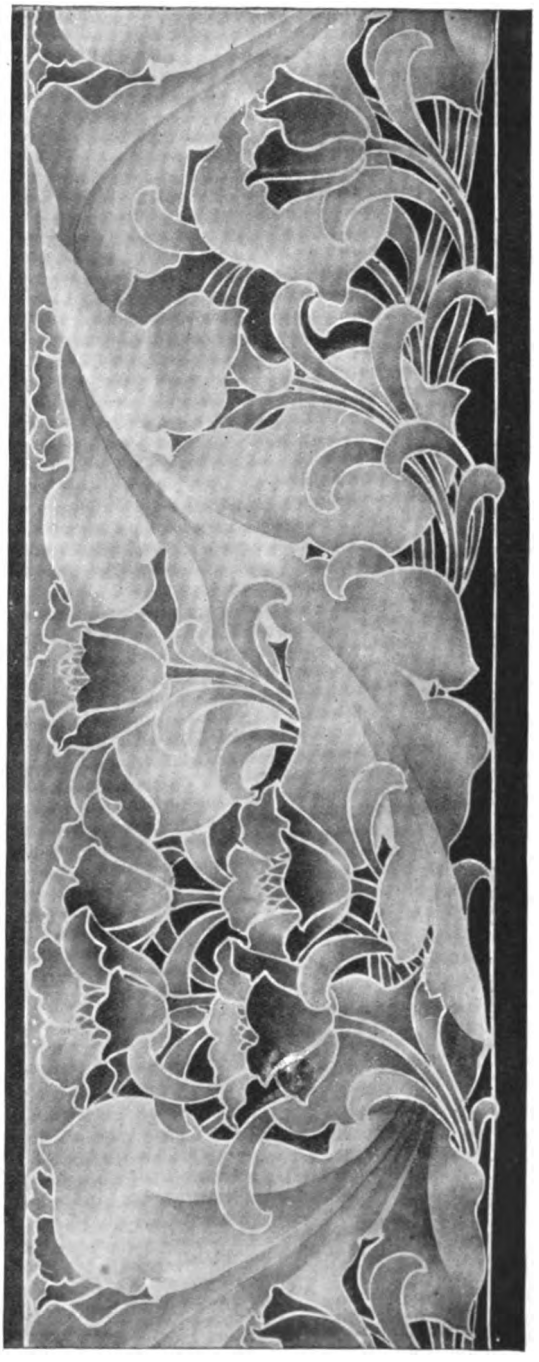

FIG. 3.—A HAND-STENCILLED FRIEZE.

The approval of landscape friezes as a means of domestic decoration is by no means unanimous. Their growing popularity is probably due to the desire for something entirely different from the ordinary pattern border which has been in use so long

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Figs. 2 and 3 are examples of hand-worked stencil friezes, the distinguishing features of which are (1) the bold drawing, and (2) the blended colouring. They are usually employed over plain grounds, such as ingrain papers, and they produce excellent effects. The blending of the colours is done by hand, but cannot be successfully copied in machine work. Even where actual blending is not employed the graduation of colour is often used. Some of the figures shown in the design are thus graduated in colour from dark to light. This is effected by using a very moderate amount of colour on the stencil brush, and this becomes almost exhausted before the lighter portions are reached. The particular designs shown in Figs. 2 and 3 are the products of a well-known firm of Berners Street, London.

Another recent departure in wall decoration is the use of coarse fabric, the best known variety of which is called "Fab-ri-kon-a." It is pasted on the wall, and gives a level surface of great durability. It serves the useful purpose of preventing the wall cracking. The material is supplied plain and also in a large variety of different colours. It may be stencilled upon, but is more frequently used without ornament, producing a rich and dignified appearance and proving very durable in use. The texture is purposely made coarse in order to break up the surface, which it does most effectually, adding greatly to the artistic effect of the decoration considered as a whole. Students who have not had much experience with materials of this kind are recommended to try the experiment of stencilling a simple design on a perfectly plain surface paper of any desired colour, and then stencilling the same design in exactly the same colours on a piece of canvas of the same hue as the plain ground. The marked difference in the effect will be very plain. A second experiment of the same kind is to run over a design the tool used by grainers and called a "check-roller" or "over grainer." This leaves a number of parallel broken lines which greatly modify and soften the appearance of a pattern. The tool should be used with black and be drawn first horizontally and then vertically.

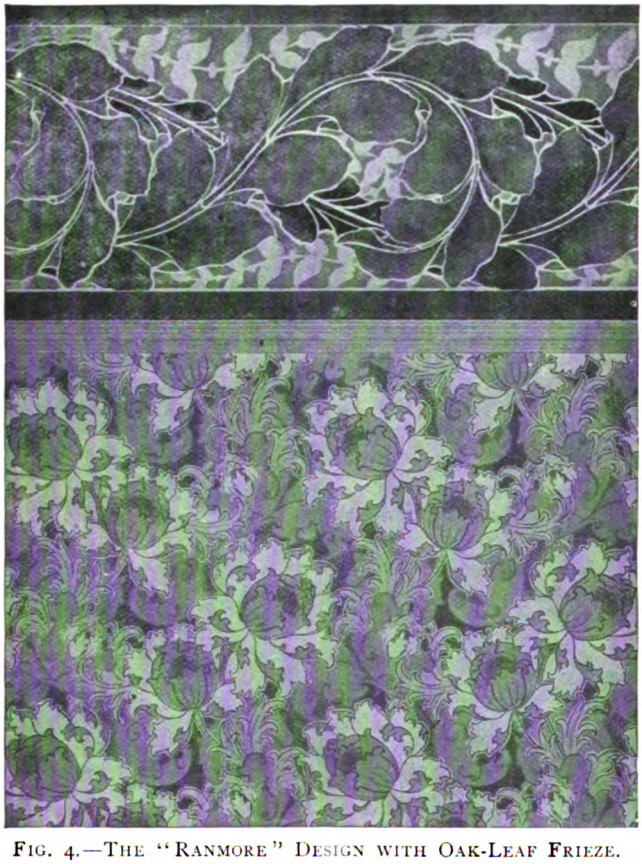

FIG. 4.—THE "RANMORE" DESIGN WITH OAK-LEAF FRIEZE.

Another important departure in the treatment of mural surfaces is the use of what are known as water paints, which have increased very rapidly of late. They may be described as "Washable Distempers," but they are greatly superior to ordinary distempers from the fineness and finish. Some very charming results may be had from their use, and we may refer to them at greater length later.

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THE MODERN ART OF DYEING.

By REGINALD BROWN, F.C.S., formerly of the Dyeing Department, Yorkshire College, Leeds; Assistant Lecturer on Dyeing under the late Professor J. J. HUMMEL.

INCE the year 1856, when the first coal-tar dyestuff was prepared, discoveries of new colouring matters have rapidly followed one another, the rate of progress in this direction being unequalled in any other branch of chemical industry. This is hardly to be wondered at when we remember that in the laboratories of the various colour-manufacturing works there are certainly not far short of one thousand chemists engaged in research, the object of which is the discovery of new dyestuffs and simpler methods of preparing those already known, together with the synthetic production of colouring matters at present only to be obtained from the vegetable kingdom.

Fifty Years Ago

The dyer of fifty years ago was confined to the use of some twenty dyestuffs of natural origin, and with these he was expected to produce a great variety of colour effect, whereas the dyer of to-day has at his command many hundred distinct colouring matters, by the aid of which he can not only imitate every colour previously produced with the natural dyestuffs, but in addition can obtain many effects formerly unattainable. The hundreds of products now available for dyeing share between them some thousands of different names, since the same dyestuff is frequently designated differently by each manufacturing firm, a circumstance which considerably adds to the dyer's difficulty in his selection of colouring matters.

Not only is this army of chemists constantly endeavouring to add to the number of useful dyestuffs, but also several hundred other chemists and technologists are employed in the colour works in striving to improve the methods of application to the textile fibres of the dyestuffs already introduced, and the information resulting from their labours is being scattered broadcast amongst those engaged in the dyeing industry. The effect of this, added to that of the establishment of technical schools and colleges in this country and abroad, is that dyeing, once regarded as a secret art, has become an art whose principles, at any rate, are to be acquired by anyone possessed of the necessary ability.

There is this much to be said for the dyers of the past, that although they possessed but a few dyestuffs, yet they generally knew these very thoroughly, and knew how to apply them to the best advantage, for the mere fact that they had so few drove them to seek all possible methods of application by which they might vary the colour. This was done by the use of various mordants and additions to the dye-bath, many of which are almost unknown to the modern dyer.

In reading the books on dyeing published during the early part of the last century, such as those of Bancroft, Napier, and Berthollet, we often come across a detailed account and investigation of a single dyestuff, its properties and methods of application, extending perhaps over fifty or more pages. To-day, when every week sees some addition to the number of colouring matters, such an extended examination of any, save one or two of the highest importance, would be impossible to the writer of any general treatise on the subject.

Some Useful Mordants

The most useful mordant of the wool dyer, bichromate of potash, was not known to the dyer of fifty years ago, who depended on the use of salts of iron and copper for dark shades, and those of aluminium and tin for bright colours. These mordants were employed in various combinations, and the natural dyestuffs were also mixed together, often to the number of five or six, to produce a single colour, which would now-a-days be readily obtained with, at the most, three coal-tar dyestuffs. In a work on dyeing, published less than twenty-five years ago, the receipt given for a slate colour on wool directs the use (for 100 lb. wool) of 4 lb. logwood, 2 oz. camwood, 1 lb. fustic, 2 oz. sumac, and 2 oz. indigo extract, "saddened" with ¼ lb. copperas and ½ lb. argol. In the same work we have a receipt for dyeing a yellow on shoddy, which would be almost unintelligible to the dyer of to-day; it runs: "Clear the water with perchloride of tin, and boil 50 lb. bark for half-an-hour. Add ½ lb. white glue, previously dissolved; boil up, and skim. Dissolve in the clear liquor 3 lb. oxalic acid, 3 lb. tin salt, and 1 lb. bichloride of tin. Boil the goods for an hour."

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New Colouring Matters

An important result of the constant introduction of new colouring matters and modification of processes for their application, is that dyeing is happily no longer to be learnt merely as a collection of receipts, but as an art depending on well-founded scientific principles. There will always be a number of dyers whose knowledge of the subject is of a rule-of-thumb character, and depends on the use of definite receipts handed down to them from some other dyer of the same type; but the tendency is more and more for the dyehouse to be in charge of a scientific colourist who thoroughly understands the principles of dyeing, or for the dyer to work in friendly conjunction with a chemist, so that the operations of the dyehouse are directed with practical ability and scientific knowledge. A dyer whose knowledge is only of dyeing receipts, when brought into contact with new conditions, such as different quality of material or of water, or dyestuffs differing slightly from those to which he is accustomed, cannot readily adapt his knowledge to the altered circumstances, whilst the more enlightened modern dyer, transported to new conditions, soon finds himself at home, and, meeting with a new dyestuff, is enabled by means of a few simple experiments, even without the aid of the copious information supplied by the colour manufacturers, to classify it according to its applicability to the various textile fibres, and to assign to it its probable value for his own purposes. In doing this he would perform dyeing trials on a small scale, and would probably first ascertain whether the colour were capable of dyeing wool or cotton direct, or required the aid of a mordant. In the former case he would distinguish between an acid dyestuff suitable for wool dyeing, and a direct cotton colour capable of dyeing cotton without a mordant, or, again, a basic colour dyeing wool direct and applicable to vegetable fibres with the aid of a tannin mordant. If the colour required a mordant, further experiments would show which mordant gave the best results. After learning in this way how the dyestuff should be applied, and thus relegating it to its proper group, he would make a series of tests for fastness, subjecting the dyed material to various agencies—light, water, soap, acids, alkalies, etc. From the result of these tests he would deduce the probable uses of the colour and its adaptability to the purposes of his own branch of the industry.

Experimenting with a New Dye

With the great number of dyestuffs now at our command, we can frequently dye a given colour on a textile fibre with twenty or thirty different dyestuffs or combinations of dyestuffs, and the colours so produced may differ, each from the others, in those properties which influence their selection for a given purpose. Stress may be laid, for example, on the behaviour of the colour in artificial light, since it is well known that dyes differ greatly in this respect, or on the fastness of the colour to light and air, as in the case of cloth intended for wear at sea, or on the fastness to washing, as in many classes of coloured cotton goods; or it may be required that the dyed threads woven into a fabric, together with white threads, may withstand a bleaching operation, and so on. It is, therefore, impossible to say which of two dyestuffs is the best, all depends on the purpose for which they are required; as a further instance, in choosing dyes for carpet yarns, the chief emphasis is, or should be, laid upon the fastness to light; whilst, should the colour be intended for wool to form coloured stripes in blankets, it must be fast to washing and to the milling process which the blankets undergo in the process of manufacture—and here fastness to light would be a secondary consideration. Therefore while the Eosines and Victoria blues are largely used in the blanket industry, nothing could be less suitable for dyeing carpet yarns.

Fastness of Colours

The term "aniline colours," still often misapplied to the coal-tar dyestuffs as a whole, has been, and to many of the uninitiated still remains, a term of reproach, implying everything that is crude in colour and deficient in fastness. The name was correct enough for the earliest coal-tar colours, since in the manufacture of these, *e.g.*, Magenta, Hoffmann's violet, and Soluble blue, aniline is a necessary intermediate product. The starting-point for colouring matters of this class is benzene, the chief hydrocarbon contained in the "light oils" distilled from coal-tar, which is converted into nitrobenzene, and this by reduction into aniline. On oxidation under suitable conditions, aniline yields Magenta, which is not only itself a colouring matter, but also the raw material for the manufacture of several others. These are for the most part wanting in fastness to light, and yield somewhat gaudy hues of red, purple, blue, and green, which were all but unknown when the natural dyestuffs were the sole source of colour for textile fabrics; hence the outcry against "aniline dyes."

Aniline Colours

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However, the hydrocarbons occurring in the heavier portions of coal-tar, the chief of which are naphthalene and anthracene, soon began to yield their quota of colouring matters, and these, especially the derivatives of anthracene, now furnish us with colours which equal, and even surpass in fastness, those derived from natural sources. These derivatives of naphthalene and anthracene cannot, by any stretch of meaning, be truly designated "aniline colours," and the term "coal-tar colours" is the only one which should be employed when referring to the whole series of colouring matters derived from coal-tar.

Alizarine Colours

The synthesis, in 1869, of Alizarine, previously known only as the chief colouring matter existing in the madder plant, has since been followed by the introduction of a long series of anthracene derivatives of extreme fastness, usually known as the Alizarine colours, and naphthalene has yielded an even larger number of dyestuffs possessed of varying fastness to light, from the fugitive naphthol yellow to the fastest black for wool dyeing, the so-called Alizarine black. Looking back at the natural dyestuffs used fifty years ago, madder has been replaced by Alizarine, cochineal by the Azo scarlets, logwood has been displaced from its pre-eminence as a black dye by various substitutes, and now indigo is in its turn engaged in a life-and-death struggle with the synthetically prepared indigotin ("artificial indigo"), identical with the colouring matter of the vegetable product.

Coal-Tar Dyes

We have now a sufficient choice of fast dyes, derived from coal-tar, to enable us to dye almost every shade on every variety of textile material. The ideal is, of course, that only those dyestuffs should be used which furnish colours fast to light and washing; but here considerations of cost intervene. The fastest dyes are, unfortunately, as a rule the most expensive to produce, and the low cost at which certain textile materials are manufactured and sold precludes the use of expensive colouring matters. For instance, an Alizarine blue or black, such as would be employed for dyeing an expensive West of England serge, would be economically out of the question for a cheap shoddy cloth. A similar relation exists between different classes of cotton fabrics.

In considering the relative fastness of the various coal-tar colours at present in use, (although, of course, all degrees of fastness with respect to various agencies exist) it is possible to classify the colours into groups which approximately indicate not only their fastness, but also their mode of application. Commencing with the dyestuffs employed in wool dyeing, we may distinguish three such groups, including respectively colours of good, moderate, and inferior fastness. The first group comprises the mordant-dyeing colours, usually known as "Alizarines," although many of them are chemically far removed from Alizarine. They are usually applied by first mordanting the wool with bichromate of potash and an acid or acid salt, and then dyeing in a separate bath with the colouring matter; occasionally, to increase the fastness to milling, a small addition of bichromate of potash to the dye bath is also made towards the end of the dyeing operation. In this first group we must also include indigo, which, though not a mordant colour, possesses great fastness to milling, and, except in pale shades, is also fast to light.

Acid-Mordant Dyes

The second group includes the comparatively modern acid-mordant dyestuffs which are dyed in an acid bath with sulphuric or acetic acid, an addition of bichromate of potash being made to the bath after boiling for a certain time. This addition, which sometimes consists of chromium fluoride instead of the bichromate, serves in some cases to develop the colour, and invariably tends to fix it more firmly on the fibre. The colours so produced are inferior in fastness to the Alizarines, but superior to the ordinary acid colours which form the third group.

For the acid colours no mordant is required, the dyebath containing only sulphuric acid and sulphate of soda, in addition to the colouring matter. A few acid colours are distinguished by considerable fastness to light or milling; they are, however, mostly inferior in this respect, and chiefly useful on account of the simple and rapid mode of dyeing, and lower cost.

Similarly, in cotton dyeing we may distinguish three groups, and again, the first and fastest group consists of the mordant colours. These are somewhat difficult to dye on cotton; their chief use is in the dyeing of Turkey-red with Alizarine, a complicated process involving a large number of operations. To the number of fast colours must be added Aniline black, produced directly on the fibre through the oxidation of aniline, and also the sulphide colours, a group of dyestuffs of recent introduction, the constitution of which is not yet exactly known. Dyes of this class have been discovered which yield black, blue, dark

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green, yellow, and brown colours of very good fastness. The sulphur dyestuffs are insoluble in water, and require to be dissolved in a solution of sodium sulphide. Two other new dyestuffs, Indanthrene and Flavanthrene, are also of great fastness, and should be included in this group.

Sulphur Dyes

Dyes of *moderate* fastness are produced when the direct colours are subjected to an after-treatment, either with a metallic salt, or by diazotising the colour on the fibre and developing with an aromatic amine or phenol. The best known colour of this class is Primuline red, produced by dyeing with Primuline, diazotising with nitrous acid, and developing with beta-naphthol. Blue, black, and brown colours may be produced in an analogous manner. The colours resulting from preparing the fibre with naphthol, and subsequently passing through the solution of a diazotised aromatic amine (*e.g.* paranitraniline, naphthylamine, chloranisidine) are also to be reckoned in this group. All these dyes are of excellent fastness to washing, but lacking in fastness to light.

The third group of cotton colours may be subdivided into the basic dyestuffs, *e.g.*, Magenta, Methylene blue, applied to cotton on a tannin mordant; these are of considerable fastness to washing, but not very fast to light; and the direct or substantive colours which dye cotton without any mordant, and are, with certain exceptions, of no great fastness to washing, and only moderately fast to light.

The above classifications are, of course, only approximate; the group of mordant dye-stuffs includes, for example, the almost perfectly fast Alizarine blue and the far inferior Gallocyanine; again, among the acid colours are numbered Tartrazine, which is exceedingly fast to light, and Naphthol yellow, which is just the reverse. The grouping indicates, however, in a broad way, what are the alternatives in choosing a colour for any particular purpose. The natural dyestuffs which still remain in use—logwood, fustic, and catechu—would be included in the group of fast colours, and the same applies to the mineral colours occasionally used for cotton, *e.g.*, Prussian blue. Logwood black, however, is only of moderate fastness to light.

Classification of Dyes

The tendency, at present, is in the direction of an increased demand for fast colours, and this demand the dyer is more and more in a position to meet owing to the simplification of the methods of producing fast colours, and the introduction of new colouring matters of excellent fastness. Indigo dyeing, formerly considered one of the most difficult and complicated operations, has been rendered more systematic and easier to carry out, as a result of the detailed study of this colouring matter due to its synthetic preparation. The older fermentation vats are giving place in many instances to the chemical vats, in which the reduction of the indigo is brought about by well-known and thoroughly understood chemical processes, instead of by a bacteriological action regulated with considerable difficulty.

A number of dyestuffs exist whose properties render it impossible to classify them as basic, acid, direct, or mordant colours. At the present time two such outsiders possessing great interest are the colouring matters Indanthrene and Flavanthrene, of which mention has already been made. These dyestuffs, which are only suitable for cotton and other vegetable fibres, possess an unusual degree of fastness. Chemically, they are derivatives of anthraquinone, the chief intermediate product in the preparation of Alizarine from anthracene, but they appear to have nothing in their dyeing properties to connect them with the Alizarines, for, whereas the latter are specially suited for wool dyeing, the new dyestuffs must be applied in a strongly alkaline bath and their use for animal fibres is thus precluded. The method of dyeing Indanthrene resembles that sometimes used for indigo; the colouring matter is brought into solution in a reduced condition by the addition of hydrosulphite of soda and caustic soda, and from this solution the cotton takes up the colouring matter. The true colour is only developed by oxidation during the washing and soaping which follow the dyeing process.

Unclassified Dyes

Indanthrene S, the older brand, dyes a bright reddish blue; Indanthrene C, a brominated compound of Indanthrene, yields a greener shade more similar to that of indigo. Flavanthrene, which in the dyebath appears a bright purple, becomes, on subsequent washing and soaping, golden yellow. All three dyestuffs are fast to light, water, soap, acids, etc.; Indanthrene C and Flavanthrene also withstand the action of chlorine.

In the allied industry of calico-printing, during the past half-century, advances have been made on parallel lines to those here described in connection with dyeing, but space forbids a detailed description of the methods now in use. In this branch it is

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usual for the operations of practice to be under the supervision of a trained chemist, whose task it is also to investigate each novelty as it appears, and adopt for practical use such as furnish useful results.

A Wide Field for Research

Although great advances in many directions have been made in the dyeing and printing industries of late years, there still remains a wide field for research. From a practical point of view, what is desired is the discovery of new dyestuffs which can be applied in as simple a manner as possible and will yield the fastest possible colours, also the simplifying of the methods of application of older colours. The chemist may also aim at the synthesis of the colouring matters of logwood, cochineal, and the various red and yellow woods. Much has already been done in this field, notably, the long series of investigations by A. G. Perkin on the constitution of the natural yellow colouring matters; but the actual syntheses of Naematein, Carminic acid, and Morin, still remain to be achieved.

Problems for Solution

Among other problems awaiting solution are the production of a red on cotton which shall be equally fast in all respects with Turkey red, and be capable of easy application; also the production on all fibres of pink colours of satisfactory fastness to light. These and numerous other problems offer themselves to the would-be investigator in the domain of colouring matters. Although it can scarcely be expected that the coming years will show a rate of progress in the dyeing and calico-printing industries equal to that of the past half-century, yet there is little doubt that much will be done in perfecting the details of already-known processes, and enabling the colourist constantly to improve the quality of his work, and to produce colours which shall satisfy, by their endurance, our practical requirements, and please, by their beauty, our artistic sense.

TECHNICAL INSTRUCTION FOR CHAUFFEURS.

By SIDNEY H. WELLS, Principal of Battersea Polytechnic.

DURING the past few months an interesting experiment has been conducted at the Battersea Polytechnic in the technical training of chauffeurs. The suggestion that such work was needed is due to Mr. Mark Mayhew, the well-known founder and commandant of the Volunteer Motor Corps, who brought it under the notice of the London Technical Education Board, through which body it reached the polytechnics. Having already carried on successful classes for cycle and motor makers, the Battersea Polytechnic decided to put the idea into practical shape, and a special course of instruction for the training of motor-car drivers and attendants was organised and commenced in September last. At the outset it was laid down that the object of the classes was to provide such instruction as is necessary for an intelligent understanding of the principles, construction, and working of motors and cars, and that in admitting students preference would be given to persons desiring training in order to earn their living as chauffeurs, and to those possessing some workshop experience. The number in the course was limited to sixteen, but so many applications were received that a second course was filled up during the first week, and places booked for other courses after Christmas. Each course has extended over thirteen weeks, meeting on two evenings a week, and including lectures and drawing, with workshop practice and practical work. In the lecture classes attention was first given to the principle, construction and working of the motor and its connections, the instruction being illustrated by working models and diagrams. The students examined and made sketches of the chief details, so that they might fully understand their construction. Then they were taken to the workshop, where small motors provided with all the necessary fittings were handled, taken to pieces, and again put together in working order. Further lectures followed, on carburettors, ignition appliances and other important parts, and these were explained, sketched, and handled in the same way. Concurrently with this, different forms of small motors

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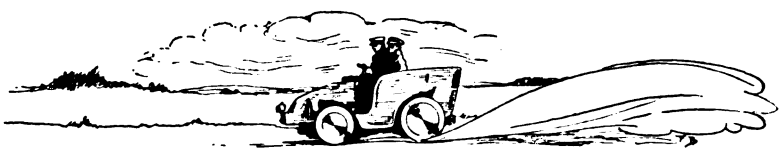
were run in the workshop, each student having to start, run and stop, and to do this when the motor had been purposely put out of order in the many different ways in which motors on cars may give trouble. Attention was then given to driving and steering gears, typical forms of gears being explained, sketched, taken to pieces and replaced. In the same manner the tubes and tyres of a car wheel were removed, repaired and refitted. Then followed lectures and demonstrations with cars of different construction, in connection with which it may be mentioned that Lieutenant Windham, of the Motor Volunteer Corps, showed his interest in the movement by giving two lectures on the construction and working of two different types of cars, with many practical hints on driving and repairs. A "Vauxhall" car was also described and handled. In the workshop class instruction was in the meantime being given in grinding and setting of valves, and in the use of tools sufficient for the making of such small repairs as a chauffeur ought to manage for himself. Towards the end of the course the students were taken out for a half-day in small parties and allowed to handle and drive a car in turns under the direction of a skilled driver, and their efforts to steer the powerful modern cars, lent for the purpose by Messrs. Friswell and Sir George Newnes, gave considerable amusement to the passers-by on a neighbouring common. The courses ended before the Christmas vacation with a test of each student, which included a written and drawing paper, and an evening's practical work with the motor, gear-box, and wheel tyres, and the making of some small repairs, a certificate being given to each student, which recorded his attendance at the classes and the result of his examination test. The courses so far have not included instruction in driving beyond that already mentioned, but so strong is the opinion of motorists who have interested themselves in the work that such instruction is necessary, that it is intended to include it in future courses. The certificate should then be evidence that its owner possesses a sound knowledge of the working and driving of a car sufficient to qualify him for a post as chauffeur. How far they will be recognised for this purpose has yet to be seen, but it is part of the scheme of the Polytechnic to help in this direction, and, as the courses develop, to apply such tests before granting certificates as will serve to guarantee the intelligence and skill of the holders. The experiment is believed to be the first of its kind, and influential motorists who have shown their interest in it are enthusiastic in its praise, and in believing that its extension will supply a long-felt and increasing need. Up to the present time the would-be chauffeur has had to pick up his knowledge of motors and cars as best he could from trade journals or text-books, and to pay a long price for lessons in driving. If, as is claimed, the training of capable chauffeurs will materially promote the use of motor-cars, then one of the chief aims of technical education in developing an important industry will be achieved, while to assist a body of workers to higher knowledge and intelligence and a more remunerative means of livelihood is surely not less important or unworthy of the work of a technical institution.



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SOME SUGGESTIVE SCHEMES OF TEXTILE DESIGN AND MANUFACTURE.

By PROFESSOR ROBERTS BEAUMONT, M.I.M.E., Director, Textile Industries' Department, Yorkshire College.

TO design is a work or process of invention, but one in which the faculty of imagination is curbed by the demands of economic construction. If the only end to be achieved were the manufacture of a new style, however apparently simple or elaborate that might be in character, the task of the designer and manufacturer would be rendered comparatively easy. But modern methods and sequence of processes have, in the first place, produced such a variety of yarn structure; in the second, such facilities for the acquirement of diversity of texture; and in the third, subjected the woven fabric to such methods of finishing, as to make the field of exploration for textile freshness impossible of being traversed within the ordinary range of experience, training, and observation. It is only the student who has a limited acquaintance with the principles of manufacture and the systems of constructing woven fabrics, who asserts, with any degree of confidence, that he is conversant with any one branch of textile design. The deeper and more complete the knowledge and field of experiment covered, the less the assurance of comprehensiveness.

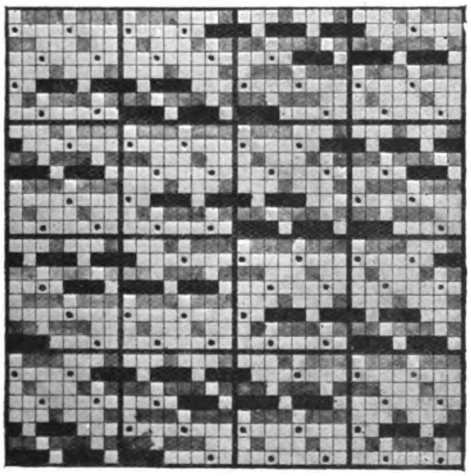

FIG. 1A.

Each distinct type of woven design, when investigated, provides scope for the exercise of ingenuity and inventiveness, and is also a subject for experiment. In line and small figury effects, which might appear restricted enough, we find suggestive examples of the law that any definite scheme of work in the loom, by the correct use of different materials, diameters of yarns, and gauge of texture, will give patterns of real excellence and commercial merit.

A large proportion of present-day styles in fabrics for wear have consisted of such patterns, but many of them have owed their novelty to the use of special or fancy yarns. In the production of the examples, full of technical detail and weave ingenuity, ordinary yarns have been used, the diversity of style being chiefly a resultant of weave construction and colouring.

Constructive Qualities of Design

One phase of design, purely technical and distinct from artistic relations, is that of constructive soundness: in other words, the combination of warp and weft interlacings, which, whilst forming the requisite pattern, will produce a fabric satisfactory in build or structure. Regularity of grouping of the floats of warp and weft will necessarily secure this quality of design, but, as seen from the designs and patterns illustrated, such is not always possible if the textural surface of the fabric is to be varied in character.

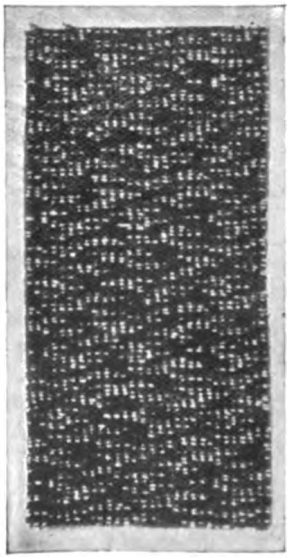

FIG. 2.

In a constructive sense, Figs. 1A, 2A, and 3A may be said to have been developed on the same base,

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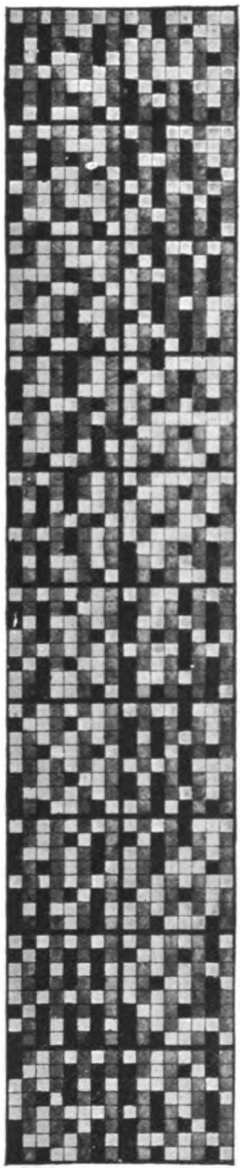

FIG. 2A.

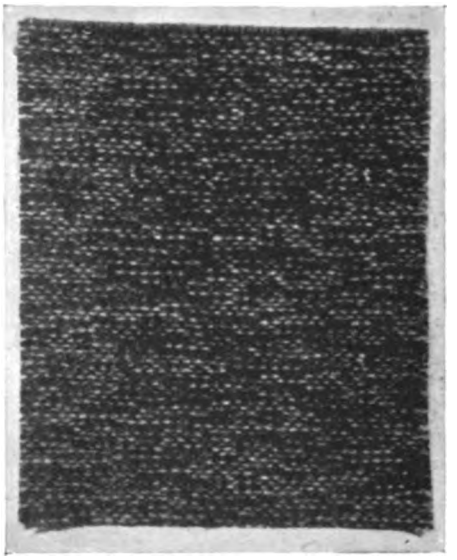

FIG. 3.

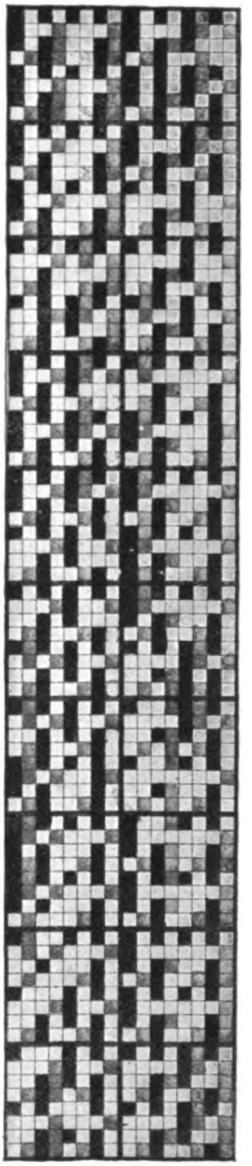

FIG. 3A.

namely, a compound of two or three twilled elements, but in the latter there are extended floats at intervals, so distributed as not to affect the constructive efficiency. Increased firmness of construction is obtainable, with the figured or spotted effects composed of twill, by using plans in which a portion of plain interlacing occurs on each pick of the weave.

The influence of frequent crossings of the yarns is to reduce the power which the construction possesses for receiving picks of weft in a given length of fabric. This difficulty is met, and yet a similar firmness acquired in Fig. 5A, when the plain weave is changed from a single to a double fabric.

Small design details always suffer in clearness of definition unless grouped on a base suitable to the development of their special qualities. Where the details are of an indefinable character, effective schemes of arrangement may be

Location of Effects

FIG. 4.

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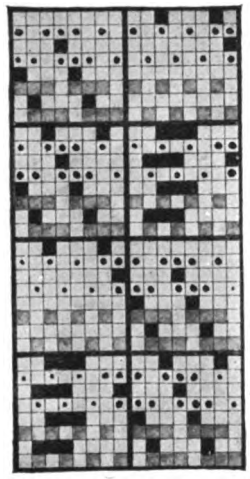

FIG. 4A.

contrived on no mathematical system. Their origination becomes entirely a work of mental contrivance. Many of the best specimens of Japanese craftsmanship show a type of design only producible by the mind of the craftsman working on original lines or depending upon his own ingenuity. Only those possessing trained imaginative faculty can devise this type of woven effect, each design being a law in itself and not necessarily in harmony with the canons of applied art.

This will be better understood if Fig. 1A be contrasted with Fig. 6A. Obviously, some mathematical arrangement has been observed in the former, but neither this nor any other prescribed base has been observed in the latter, which becomes more complex and interesting as a grouping of small effects when extended, as in Fig. 6A. There is a similar intermingling of effects in Fig. 2, whilst clearly there is an ascertainable mode of distribution in Fig. 10.

The more minute the effect, the more ingenuity necessary to acquire clearness of pattern without there being any fixed repetition traceable. Fig. 3 is typical of this kind of textile contrivance. It is a broken line pattern, but the mottled colouring and the method of locating the shades conceals the plan on which the pattern is constructed. Fig. 4, of which Fig 4A is the design, is distinctly a detached spotted pattern, but here again the irregularity of surface detail is noticeable. A more forcible contrast of

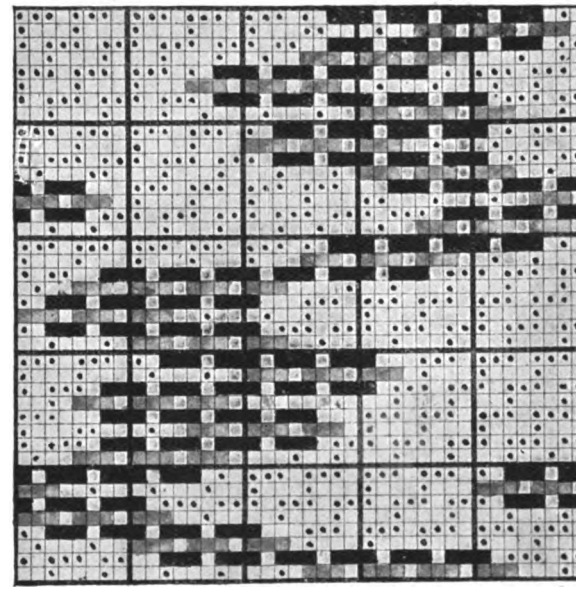

FIG. 5A.

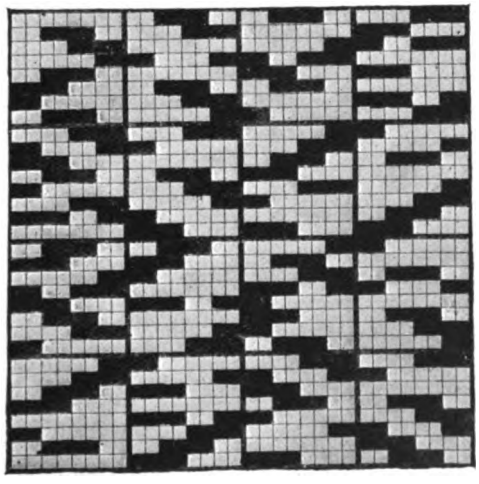

FIG. 6A.

effect is seen in Fig. 8, and the method on which the pattern is devised is not so indistinct, yet by appropriate subdued connections of the larger irregular-shaped white spottings with each other, such an intermingling of detail is obtained in the ground work as to prevent the immediate detection of the system of design practised.

Colour Intermingling and Arrangement

By whatever method colour is applied to a woven fabric, harmony or contrast is largely influenced by the subtil'y with which the colours are intermingled. One elemental law underlying such colouring is that the several hues retain their distinctiveness; not that it is impossible to obtain perfect blending or shading of hues, but rather that each retains its individuality in the fabric. Even when

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the colour blending is effected in the fibrous condition, and when such fibres have been, by mechanical transpositions, brought into the form of a thread and subsequently of a fabric, yet on close examination the several colours may be distinguished from each other. This quality of colouring is more emphasized when the blending of hues occurs in the yarn form. Though in the weaving there may be complex changing of the positions of the

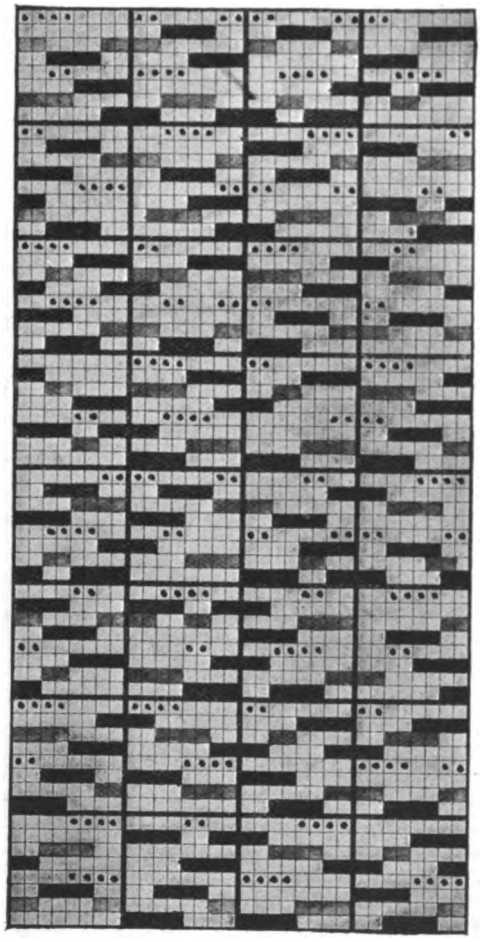

FIG. 6B.

threads, yet the process of colour mixing is neither so subtle nor so complete as in the co-mingling of fibres in carding.

This aspect of textile colouring must be taken into account. Just as each speck of colour has its influence on the richness of the general tone in the foreground of a painting, and its value as a colour element is determined by its individuality, so on the surface of a woven fabric the colours have a

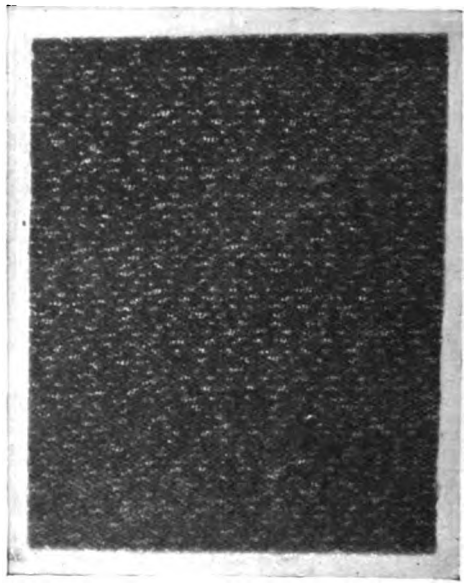

FIG. 7.

two-fold quality: first, the distinctiveness of each hue, and second, the *mélange* of tone yielded. The mingling of colours may in textiles, as in painting, be in such minute particles as to give, when not closely examined, a new resultant shade. This is particularly so in the blending of fibres and in the small effects obtained by weaving the styles typified in Figs. 2, 3, 7, and 9.

In woven designs in which coloured yarns are used, the colours may be grouped in any prescribed order or scheme of distribution.

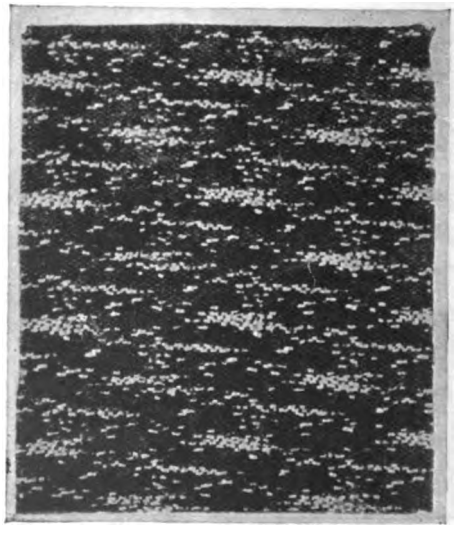

FIG. 8.

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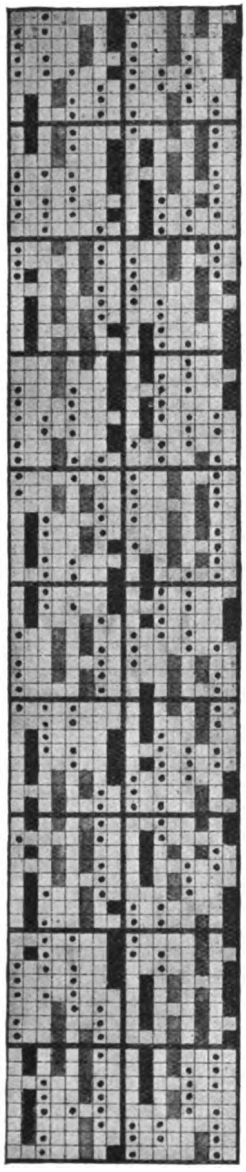

FIG. 7A.

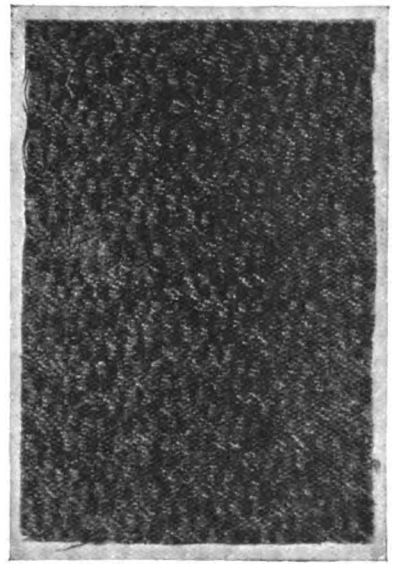

FIG. 9.

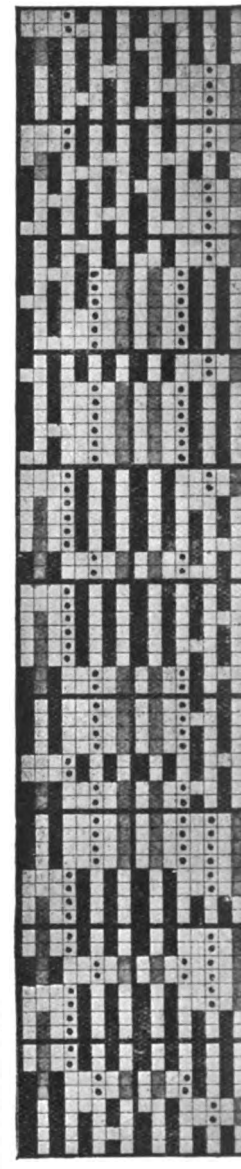

FIG. 9A.

intermingled that no one colour, though the contrast is forcible, is more pronounced than another. This broken colouring always imparts an interesting quality to the surface of the pattern providing the individual colours harmonise with each other.

Another feature which enters into the application of colour is the structure of the weave. In these examples, the effects are entirely due, as regards colour, to the weft or crossing yarn, the warp, in this respect, being an idle factor. This renders the work of

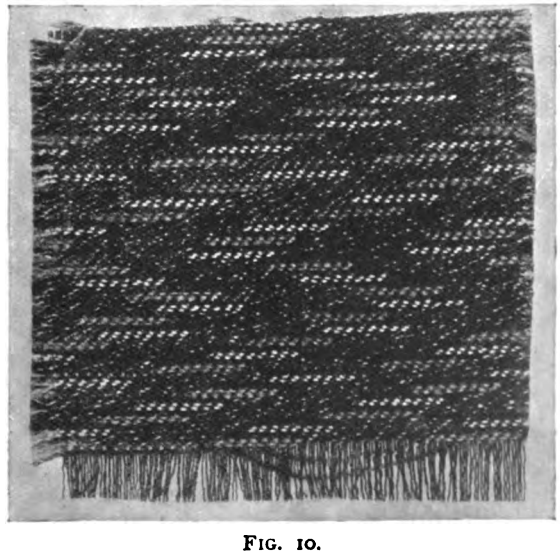

FIG. 10.

In the woven specimens illustrated, the leading idea has been to secure mingling of hue as distinguished from specific grouping. Yet a distinct principle has been observed. For example, in Figs. 7 and 9, the specks of the various hues are so

acquiring an appropriate scheme of colour distribution more difficult, each design having to be constructed to form the required effects, and yet to conceal the warp, whether the fabric be examined on the face or the under side

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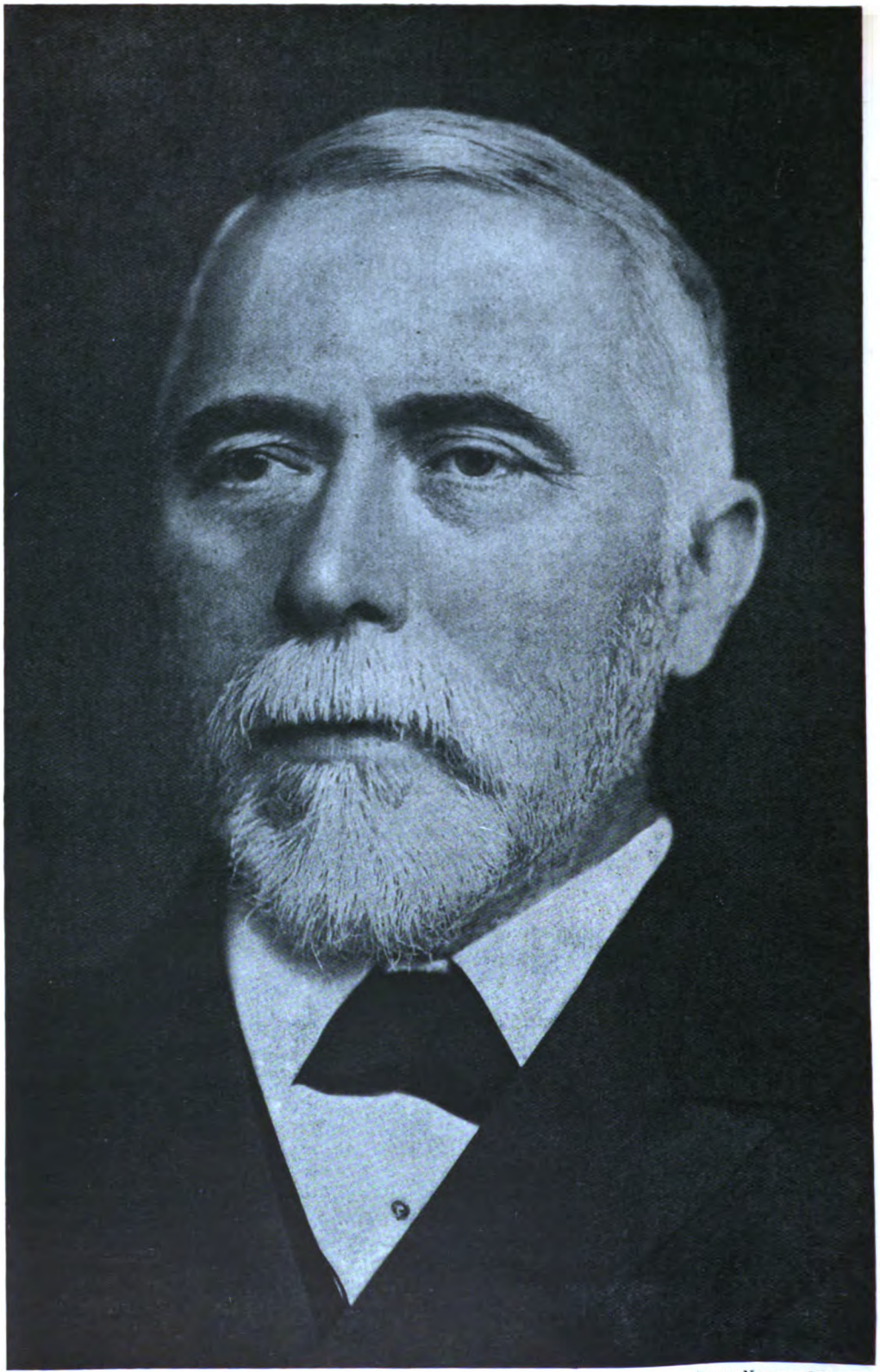

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SIR WILLIAM WHITE, K.C.B., D.SC., LL.D., F.R.S.

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ELEMENTARY TECHNICAL EDUCATION.

By SIR WILLIAM H. WHITE, K.C.B., D.Sc., LL.D., F.R.S.

THE question of technical education, as affecting the artizans and working people of this country, is one that has always been very near my heart. It sometimes happens, however, that in discussions on technical education things get a little confused, and they do so because it is forgotten that there are two distinct classes of technical education, both of them important, both of them necessary to the national well-being, and both assimilative, yet distinct.

There is first what I call *elementary* Technical Education. Some people call it *lower* Technical Education. I prefer to call it elementary; that is to say, the Technical Education that helps and brings forward the latent talents of the man who, from the accident of birth and circumstances, has to gain a livelihood and to begin work early in life. There are other young men, who have the good fortune to be better off, who can choose their profession or employment, and of course prefer to take a different kind of training. They have to begin with a preliminary training, which may be different—and usually is different—from that of the working man. The latter has ordinarily only his evening time for mental improvement and study. He has his day's work to do, and naturally his employer expects him to do a fair and honest day's labour for the wages he receives. The young man in better circumstances is able to give his days to study, and has, at the outset, an easier time. But it does not always follow that he comes out first, and eventually does better in the particular calling he may select.

Different Kinds of Technical Education

Two kinds of technical instruction are therefore required: (1) the elementary, and (2) those designed for students who are trained from the first with the intention of becoming directors, managers, heads of businesses—what I should call the higher technical training. There is a necessity for both. They are distinct, yet they are closely united. To some considerable extent the first acts as a "feeder" to the second, and will do so more and more as the great scheme of national education becomes perfected, and the elementary schools lead on to continuation or secondary schools, which will prepare students for the technical institutes, whence selected pupils will go on to technical universities. Thus will the best brains of the country be made available, and our national position strengthened.

The time has passed when the idea prevailed that technical instruction for the artisan should be limited to the workshop or the factory; skill in handicraft and knowledge of practice or precedent no longer suffice. All these qualities, combined with obedience and loyalty to employers, are as essential as ever they were. There is no disputing now that every man engaged in industrial work should, if he desires it, have an opportunity of acquiring a fuller knowledge of principles as well as of processes. For the workers themselves, such knowledge is advantageous. Work done intelligibly means better work. From well-instructed workers better work can be obtained than from others not so well informed. It is certain that with trained men there must come more valuable suggestions for improvements in methods and processes that may reduce the cost of production, and advance manufacture. In the stress of industrial competition, ever increasing in severity, it is absolutely necessary to the maintenance of our national position in the markets of the world that no advantage which technical training can give should be unrealised.

Skill alone Insufficient

In the past, a large number of leaders in mechanical invention and improvement in manufacture have sprung from the artisan class. It must suffice to quote only two names. George Stephenson was a miner who drove the engine at a mine not far from Newcastle; there, self-taught, he learnt the principles which guided him in becoming the greatest railway engineer of his time. Michael Faraday was a bookseller's apprentice, who became, by sheer force of merit, the greatest scientist of his day, and from whose discoveries have sprung the most important advances in the applications of electricity. These are only specimens which could be

Leaders in Invention

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multiplied almost indefinitely. What has been done in the past must be capable of accomplishment, and easier accomplishment, in the present and in the future. These men had to fight their way forward under very trying conditions, conditions that no longer exist. What is wanted for the national well-being is that the best ability of the country, from whatever source it may be derived, shall have its chance. It is a valuable asset of the national treasure, and must not be allowed to run to waste. In these days there is no real bar to merit, and the man who combines ability with industry can make his way upwards.

American Opinion

The other day I met an American engineer who was in charge of one of the electrical works which have been established in this country by our cousins across the Atlantic. I asked him what was his honest opinion about the British workman. He had full opportunity of judging the capabilities of both British and American workmen, and I think his opinion worth quoting. Said he: "The Britisher is the most thorough workman in the world; the reason why he does not succeed as the American does is because, in my country, there is a spirit of ambition and expectation of advancement among the men, a greater force of individuality, and a fuller recognition of individual merit." This American, I think, was a little inclined to over-estimate the conditions that exist in the United States; but without entering into questions which might cause disputes, I will simply say that when it is possible for a poor boy, whose father was an alien emigrant in the East-end of London, to rise by sheer merit to be a scholar of Oxford University, there cannot be very much amiss with our system of education. People say we are so crowded, so thickly populated, that the chance of advancement is small and competition excessive; but I say there is room enough still for those who will qualify themselves and are not afraid of hard work.

To sum it all up: elementary technical instruction adapted to the working classes is by common consent a necessity of any scheme of State-aided technical instruction. To devote attention simply to higher technical instruction, and to lavish resources upon it exclusively, or even chiefly, would be a fatal mistake in the national interest. We go abroad for examples of how to carry on technical education, and we do well to understand foreign systems thoroughly, and to profit by their experience. But there are some home lessons which we are apt to forget. We need not go abroad to learn some things; we have them here already. It is a singular fact that for sixty years in this country—and I speak with full knowledge of what is happening abroad—the Admiralty has had in operation a system of technical training for dockyard apprentices which offers results more extensive and conclusive than any obtainable elsewhere. It has produced such men as Sir Edward Reed, Sir Nathaniel Barnaby, Sir William Pearce, Mr. Martell and Mr. Waymouth, of Lloyd's, the present managers of such great shipbuilding yards as Fairfield, Elswick and Clydebank, the manager of the engine-works at Harland and Wolff's, the staff of Lloyd's, the principal and subordinate officers in the Royal dockyards, and others. In fact, it is no exaggeration to say that this system has produced the majority of the men who are now occupying the most prominent positions in the shipbuilding industries of this country. These facts conclusively establish the merits of the Admiralty system. It has given to private shipbuilding its leaders who have risen from the ranks, while it has produced men holding many important and influential positions in all parts of the world.

The Admiralty System

In this particular system admission is obtained by open competition. There is no restriction, except good health, good character and British nationality. After apprenticeship comes a certain amount of school attendance, alternating with practical work at the trades. Then follows a gradual selection, out of those who attend school in the intervals of work. Those who are found to be most capable of taking the higher training are selected to receive it and continue school attendance; the remainder cease to attend school. It is entirely a question of merit. The number is gradually diminished until, after four years' training, perhaps two or three of the ablest youths are sent, first to the Naval College at Devonport, and afterwards to the higher course of technical training at the Royal Naval College, Greenwich. In this way the Admiralty has produced a succession of able men in such numbers that they have not only manned the Royal dockyards, but have overflowed into the private industries of the country to the great benefit of the whole shipbuilding community.

Open Competition

True, out of hundreds of apprentices entering in any one year there are some

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who drop out at each stage. Can it be said that these men are disappointed because they did not attain a higher rank? Are they any the worse because they did not reach a higher goal? I like to remember some of the youths who were apprenticed with me and lived and died as working men. Many had little libraries of standard books, while others took up particular lines of private study. Though they did not get beyond the working stage, they were men anyone might well be proud to meet. Happiness does not come simply from position, or fortune, or anything outside ourselves, but from character, trust in God, and from the endeavour to do the right and to be true in all our actions.

The Admiralty system has produced men of whom England might well be proud. What the Admiralty has done large employers can also do, though not perhaps to so great an extent. Mr. D. Drummond, the Locomotive Superintendent of the London and South Western Railway, is evidently a believer in this system. I strolled into the Battersea Technical Institute at half-past eight in the morning not long ago, and found at work a class of between forty and fifty apprentices from Nine Elms; I was told that next morning there would be a junior class of sixty. Thus one hundred young fellows are attending morning classes when, as Mr. Drummond says, their minds are fresh and their bodies untired. What the London and South Western Railway do is this: they pay these boys for the time they spend in the Institute, on condition that they do home work in the evenings. Some of the lads, we know, will not continue their studies long, but they will turn out better mechanics because of this education. Not a few, we may be sure, will eventually secure influential and responsible positions. Here we have a demonstration of the practical way in which employers can help the spread of technical education. It is the same all over the country. There are many hundreds of employers who can give their young men technical instruction just as the London and South Western Railway are doing; and they, as well as the country, will profit by it. By co-ordination and joint effort much more in this direction might be done.

Locomotive Engineer Apprentices

I do not believe in simply copying Germany; but I do say that in the matter of systematic technical classes they are ahead of us. There are no less than fifty-two schools in that country—private and State schools—for elementary instruction of a technical nature. I will take one. It is to be found at Stuttgart, in the kingdom of Würtemberg. This is by no means a large kingdom. It has a population of 2,000,000 and a revenue of £4,500,000. The technical school at Stuttgart has 61 professors and assistant teachers, with about 2,000 students. The State grants to this one school each year £10,000; only £4,500 is obtained from other sources. The fee of a student there has a maximum of £5 a year, and in something like three hundred cases this fee, last year, was entirely remitted.

Systematic Training

Fifteen years ago there were no evening classes to reach the shipbuilding apprentices on the Thames, though a little town like Dumbarton offered facilities to the same class. With the aid of the Shipwrights' Company and several friends we started classes at the Bow and Bromley Institute in 1888. In 1892 they were transferred to Blackwall, and after remaining there six years were moved to West Ham. Altogether about £1,000 has been spent—not a large sum surely. We now have £4,000 in trust for continuing the work, which I obtained chiefly from shipbuilders and shipowners. Some five hundred and fifty young men, who otherwise would have had no opportunity of gaining technical instruction, have been given a fresh start in life and put upon a higher plane. It is a source of great satisfaction to me to have had a large share in the organisation and conduct of this modest but useful scheme, which has already produced many men who will go far in the shipbuilding profession. State aid and organisation are required for elementary technical education, but personal effort and interest are no less necessary to complete the success of the national system of training we wish to see established.

Shipbuilding Apprentices.

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THE CONTINUOUS-CURRENT DYNAMO.

By H. M. HOBART, M.I.E.E.

THE design of the continuous-current dynamo is generally looked upon as having arrived at a final form. While this is to a certain extent the case for some few largely employed outputs, speeds, and voltages, there is an extensive range of ratings where the widest divergence of opinion still exists as to what constitutes the most suitable design. Thus, the narrow speed limitations of the standard salient pole multipolar type have led to the development of the Deri* dynamo for high speeds. In general construction the Deri dynamo closely resembles the modern induction motor. Principles in some respects similar to those found in the Deri dynamo were formerly employed in the Thompson-Ryan machines, of which a good many were at one time built in America. Whether the Deri designs will, in practice, prove equal to the difficulties encountered as regards commutation in very high-speed work, is not yet known; but it must be confessed that the unmodified multipolar type, while it has for almost all other conditions demonstrated its superiority to modified types, is altogether inadequate for very high-speed work. With the advent of the steam turbine, and the general tendency towards high speeds in engineering work in general, it is unreasonable to suppose that no successful type of continuous-current dynamo for such work will ultimately be forthcoming.

It was not, indeed, until the difficulties encountered in designing large units for steam turbine speeds were discovered, that the natural limitations of the present standard type of multipolar dynamo came to be well appreciated, although the much more moderate speeds of the British high-speed engines had already given difficulties in many instances.

While in England there are numerous examples of continuous-current dynamos driven direct from high-speed engines, the tendency in America and on the Continent has been strongly in favour of large slow-speed sets, especially for supplying electric energy to tramway systems. This is the most favourable condition for the normal salient-pole design of the continuous-current dynamo, and it quickly reached a high standard of development for such work. The more difficult conditions, chiefly relating to commutation, encountered with high speeds, will, however, ultimately have a wholesome effect through renewed stimulation in the devising of ways and means for improving commutation. This will be in the light of a much better understanding of the phenomena involved than was possible at the period of the development of the slow-speed dynamo.

It is remarkable that, in all these years, none of the innumerable ingenious innovations and auxiliary appliances which have been devised, with a view to improved commutation, have ever been finally incorporated in the normal design, which, in its highly developed modern form, is as simple as can readily be conceived, and depends for excellence merely upon the care and judgment employed in its proportions. The carbon brush could perhaps be cited as an exception to the above statement, but its use is now of such long standing that one can hardly realise that it ever was an innovation.

Another feature, the use of slot-wound armatures, falls in much the same category. Indeed, the old Pacinotti ring and the Siemens shuttle armatures may be considered as precedents for the modern slot-wound armatures. Nevertheless the supersession* of the "smooth core" by the "slotted" type, and the practically simultaneous general adoption of drum in place of gramme ring-windings constitute important steps in the evolution of the modern dynamo.

* For the most complete description of the Deri dynamo yet published, the Electrotechnische Zeitschrift of 11th September, 1902, p. 817, should be consulted. Many engineers in many lands are at present engaged in the development of very high-speed Deri dynamos of large capacity.

* It is quite possible that the early future will see a reversion to smooth-core constructions for designs in which the higher reactance voltage accompanying slot windings offers sufficient difficulties to counteract its advantages from the mechanical standpoint. One very large and experienced concern has never admitted the inferiority of smooth-core construction, and employs it to this day in the bulk of its product. The machines built by this firm are, moreover, of excellent mechanical construction, and extensively employed. This may, however, be an instance where skill in designing has overcome inherent disadvantages of type.

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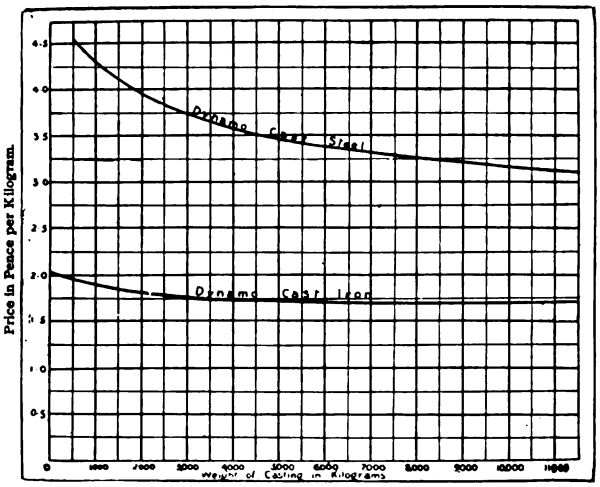

FIG. 1.—RELATIVE PRICES OF STEEL AND IRON CASTINGS.

The development of the steel casting industry has played an important part in the history of the development of the dynamo; by no means, however, an indispensable part, so far as relates to the large continuous-current dynamo, for a few of the largest manufacturers of the highest grades of continuous-current dynamo, still employ laminated magnet cores and cast iron yokes, and it cannot be denied that this type of design has very excellent features inherent to this particular choice of materials. So far, however, as can at present be foreseen, cast steel will, in virtue of the improvements constantly going on in its manufacture, largely supersede other materials for the field frame and magnet cores of the continuous-current dynamo. It is highly probable that it will be alloyed with a higher percentage of silicon or alumium, and will in consequence have a distinctly higher magnetic conductivity than the material at present commercially attainable.* Although the actual and relative prices of cast steel and cast iron vary greatly from year to year in different lands, and are also subject to special trade arrangements depending upon many circumstances, the curves in Fig. 1 may, nevertheless, be useful as giving an approximate idea of the relative prices, and their dependence upon the weight of the castings. It is the proportionality between such ratios and the relative magnetic properties,* which largely determines the comparative suitability in given cases. The prices correspond to those paid in Germany about one year ago, by the larger manufacturers of dynamos. On the basis of these prices, the tendency towards the use of cast steel should be distinctly more marked in heavy than in light work.

Another modern tendency is towards the use of several commutator segments per slot. In the earlier days of ironclad armatures, it was considered desirable to have but one, or at the most, two commutator segments per slot. This was thought to be desirable from the commutating standpoint. It was the restricted space available for tramway motors which, some eight years ago, first led to decreasing the number of slots and increasing

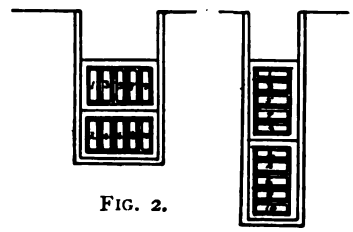

FIG. 2.

ALTERNATIVE ARRANGEMENTS FOR 5 SEGMENTS PER SLOT.

* These magnetic properties will be treated under the heading of "The Magnetic Circuit."

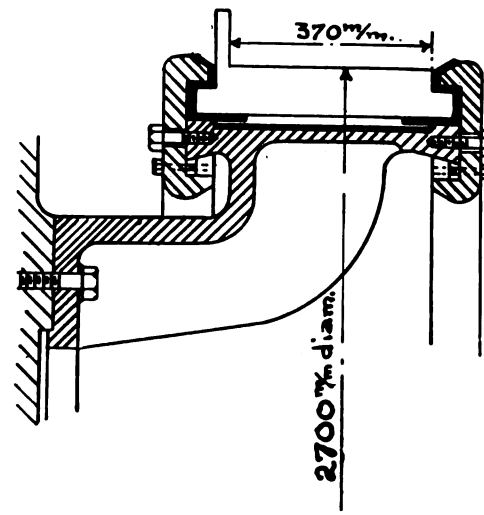

FIG. 3.

TYPICAL MODERN COMMUTATOR FOR 500 VOLT SLOW SPEED TRACTION DYNAMO.

* Those interested in these possibilities (which may ultimately be of far reaching influence) should read an important paper, entitled "Researches on the Electrical Conductivity and Magnetic Properties of Upwards of One Hundred Different Alloys of Iron," by Barrett, Brown and Hadfield, contributed to the Proceedings of the Institution of Electrical Engineers in 1902, vol. xxxi. p. 674.

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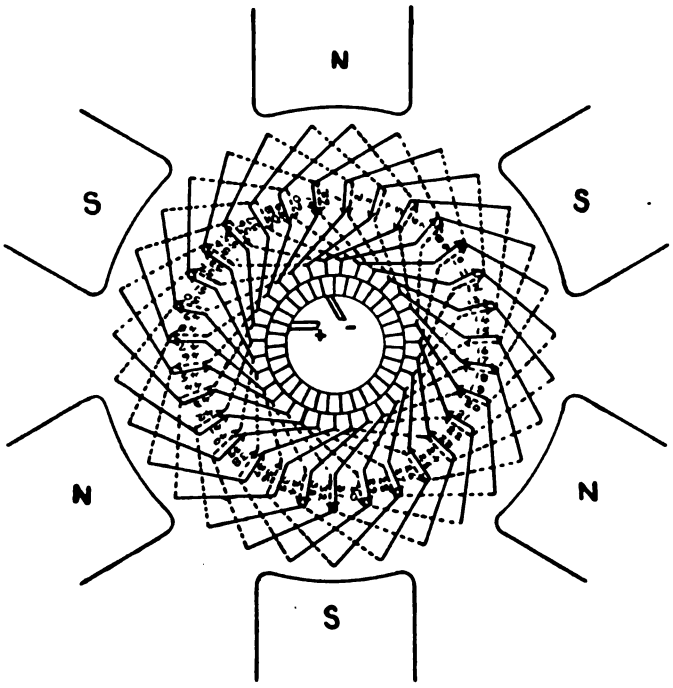

FIG. 4.—TWO CIRCUIT SINGLE WINDING.

the number of segments per slot. This permitted of decreased armature diameters, owing to the saving in slot lining insulation, and was found not to prejudice the sparking—in fact, subsequent tests of slot inductance* disclosed the fact that the inductance was actually less where many narrow slots were replaced by a few wide ones. The practice is slowly gaining ground in the design of dynamos, and three segments per slot is already common practice, four and even five segments per slot being occasionally employed. The most important limitation in this respect relates to eddy current losses in the pole shoes, when not laminated, accompanying too great a ratio of slot opening to slot depth. But wide slots are not necessarily associated with this practice, since five turns (ten conductors) per slot, for instance, may be arranged ten deep instead of in accordance with the more customary arrangement of five wide and two deep. The alternative arrangements are shown in Fig. 2. Either might be preferable according to circumstances.

The ultimate purpose of this and the following articles is to arrive at a more precise idea than has heretofore existed, as to the inherent limitations of the present normal type of continuous-current dynamo, and of the factors underlying these limitations. As essential to this end, and as incidentally useful for general purposes, the subject of the design of the straightforward unmodified type of modern multipolar dynamo will first be discussed, and a study will be made of the order of procedure calculated to lead to obtaining the best design for given conditions.

The underlying considerations may be arranged in the following order:—

A—The electric conducting circuit.
B—The magnetic circuit.
C—The insulation.

A, B and C each require to be considered both from (α) the mechanical, and (β) the thermal—A and B also from (ϵ) the commutating standpoint. Other considerations, generally regarded as results, but in reality more or less consciously controlling the designer throughout the development of the design, are (α) efficiency and (β) regulation.

While it is of importance to keep all these factors distinctly in mind, it is impossible, and moreover unnecessary, to treat them in rigidly successive order, owing to their intricate interrelations. Nevertheless, the subject may be approached by a brief preliminary consideration of A, B and C in consecutive order.

A.—THE ELECTRIC CONDUCTING CIRCUIT.

With the exception of the brushes and brush holders, and in some instances the commutator connections, the material employed for the electric circuits is exclusively copper. A minimum of testing suffices to ensure uniformity as regards conductivity within 2 per cent. or so, and higher accuracy is useless.* Specifications vary with regard to the temperature rise to be permitted in dynamos. Fifty degrees Cent. to 60° Cent. rise above surrounding air, as determined by

* See "Electric Generators," p. 160. Also for still further tests, "Modern Commutating Dynamo Machinery," Jour. Inst. Elec. Eng., vol. xxxi. (1901-1902), pp. 195 to 197.

* As a matter of fact, the attainment of uniform dimensions, especially in the finer sizes of soft wire, has been found to present the greatest difficulties from the dynamo manufacturer's standpoint.

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measurement of the increase in resistance* of the conducting circuits after the attainment of the ultimate temperature for full load, may be considered as a rather higher limit than is generally permitted. The temperature rise of the hottest accessible part as *thermometrically* determined is much more usual practice, and this is variously specified all the way from 30° Cent. rise to 50° Cent. rise. The thermometrically determined temperature rise will often be found to be less than two-thirds as great as the rise determined by resistance measurements.† In the specifications drawn up by some engineers, the temperature rise at the commutator surface is permitted to exceed by some 10° Cent. the greatest determinable rise of any other part. This, however, is probably a relic of the old conception of the commutator as an unavoidable but minor accessory. As it is now coming to be regarded, and correctly, as at least of as much importance as any other organ of the dynamo, it would appear wise to recognise the mechanical difficulties in its construction, which are greatly accentuated by these very temperature variations. The less the range of temperatures to which the commutator is exposed, the more practicable becomes the preservation of a rigidly true and concentric cylindrical surface. Given an excellent mechanical commutator construction, the expansion and contraction due to heating and cooling contribute greatly to deterioration, and the wider the temperature limits between which this occurs, the more rapid is the deterioration. This is mainly owing to the very nature of the structure, successive segments of mica and copper being secured, not directly, but with further intermediate mica insulations, to the commutator spider, by means of end flanges and bolts. A type of commutator construction employed in a recent 1000 kilowatt tramway generator is indicated in Fig. 3.

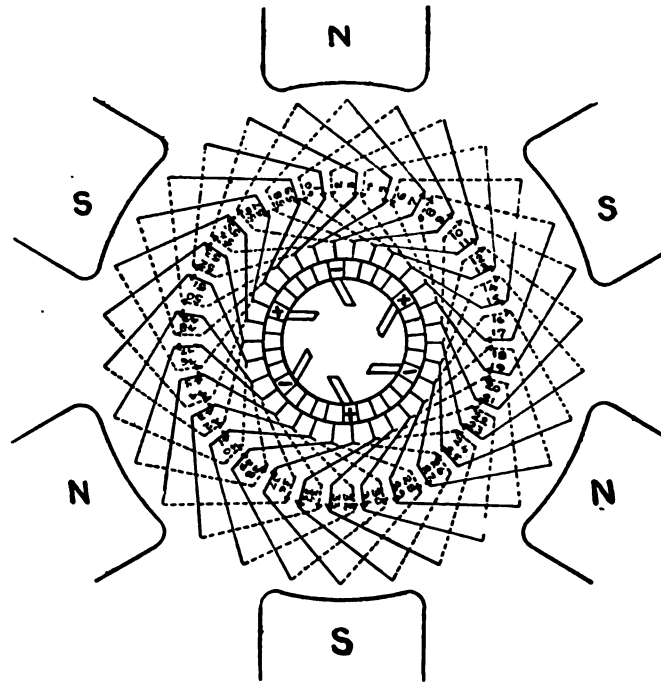

FIG. 5.—MULTIPLE-CIRCUIT SINGLE WINDING.

For the designer's purposes it is desirable to adopt some uniform temperature rise as a basis for his calculations. It is convenient to take this as 40° Cent. above the surrounding air, the temperature of the latter being assumed to be 20° Cent. The ultimate temperature is thus 60° Cent.

The specific resistance of commercial copper at 60° Cent. is approximately ·00000200 ohms per centimeter cube, *i.e.* between the opposite faces of a centimeter cube. In these articles, all resistances of

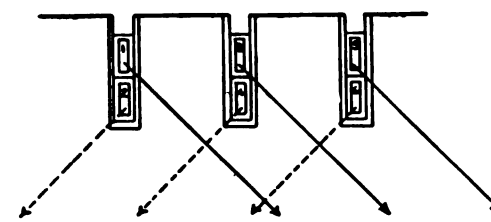

FIG. 6.—CONVENTIONAL METHOD OF NUMBERING ARMATURE CONDUCTORS.

* The resistance of commercial copper increases four-tenths of 1 per cent. per degree Centigrade increase of temperature. The internal temperature of a winding may therefore be determined by measurement of its resistance, first at a known, and again at the unknown temperature.

† The ratio of the thermometrically and electrically determined temperature increase is very dependent upon the type of construction as regards provision of ventilating ducts, depth of winding, nature of the insulating materials, and the method in which they are applied.

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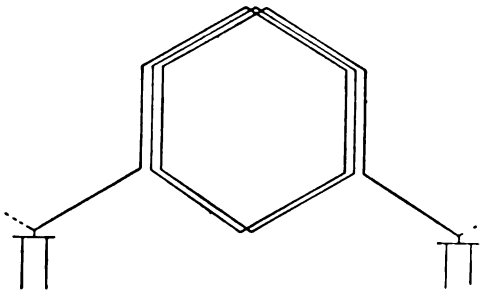

FIG. 7.—WAVE-WINDING DIAGRAM
3 TURNS PER SEGMENT.

copper circuits will be taken at 60° Cent., and the losses and efficiencies will also be taken to correspond to this temperature, which, in general, will constitute the limit of ultimate temperature rise for the designs.

In determining the resistances of the electrical circuits, it suffices to have the specific resistance (already given), the cross-section and the length, the latter being derived from the mean length of one turn and the number of turns in series. Now it is generally, so far as relates to the preliminary design, a needless refinement to determine the precise mean length of turn corresponding to the particular type of armature winding employed. It is justifiable to take the "free" length, *i.e.* the length of the end connections plus the portion corresponding to ventilating ducts and lost space generally, as being equal to

$$3\ \tau\ *$$

where τ is the polar pitch, *i.e.*, the armature circumference divided by the number of poles. The "embedded" length will, of course, be equal to

$$2\ \lambda_n$$

where λ_n is equal to the net length of armature laminations between flanges. The mean length of one armature turn is thus equal to

$$3\ \tau + 2\ \lambda_n.$$

Such a rough treatment is really in the end profitable, as time is gained for giving attention to more essential refinements.

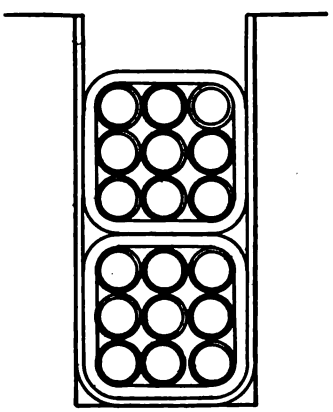

FIG. 9.—ARMATURE SLOT WITH
3 TURNS PER SEGMENT AND
3 SEGMENTS PER SLOT.

One must analyse the armature winding, and ascertain the number of turns in series and in parallel between positive and negative commutator brushes. The scope of these articles will not permit of an exposition of the subject of armature windings.* It must suffice to state that those most employed fall into two categories — two-circuit windings,

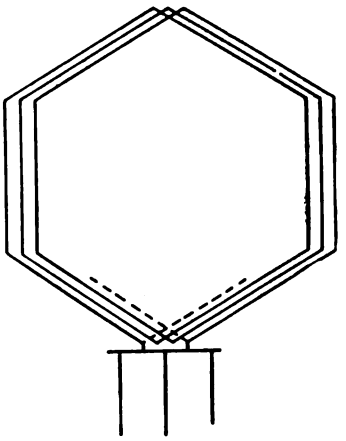

FIG. 8.—LAP-WINDING DIAGRAM
3 TURNS PER SEGMENT.

sometimes called "wave" windings; and multiple-circuit windings, sometimes called "lap" windings. The former are often employed in machines of small capacity, and are also useful for intermediate capacities

* As a matter of fact $3\ \tau$ is an outside value reached occasionally in very well-ventilated armatures of high armature strength as expressed in "armature ampère-turns per pole." $2.8\ \tau$ is a more representative value, and in "short-chord" windings and carefully designed end connections, $2.5\ \tau$ may even be approached. While it should be the designer's aim to obtain as low a value as feasible, it is nevertheless good practice to employ $3\ \tau$ for the "free" length in preparing preliminary designs.

* For detailed treatment of the subject of armature windings, reference may be made to Arnold's "Ankerwicklungen und Anker Konstruktionen," 3rd edition, 1898, Julius Springer, Berlin; or to "Armature Windings," Parshall and Hobart, 1895, D. Van Nostrand Co., New York. A recent summary of the subject may be found in the third of a series of articles entitled "Electric Motors" in "Traction and Transmission" vol. iv.. p. 206, August, 1902. See also pp. 60 to 70 of "Electric Generators," Parshall and Hobart, Engineering, 1900. More or less similar nomenclature is used in Dr. Thompson's "Design of Dynamos," chapter v., p. 78, E. and F. Spon, 1903. Many of the windings in Dr. Thompson's treatise are produced in different colours, adding greatly to the clearness of the explanations.

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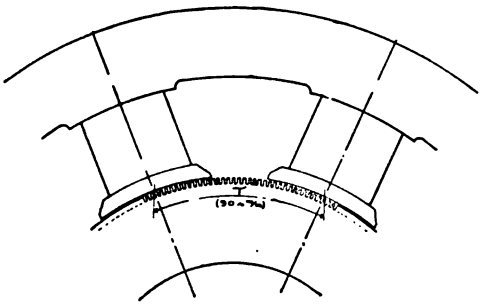

FIG. 10.—DIAGRAMMATIC SKETCH OF MAGNETIC CIRCUIT, 400 K.W. DYNAMO.

where the speed is low. They are characterised by having two circuits through the armature from positive to negative brushes, no matter how many poles there are. Each of the two circuits carries one-half of the total current. Such a winding is shown diagrammatically in Fig. 4. The multiple-circuit winding is more suitable for large machines, and is also required in machines of intermediate capacity where the speed is high. It is characterised by having as many circuits through the armature from positive to negative brushes as the machine has poles, the current, of course, dividing equally amongst all these parallel circuits. Thus in a 1600-ampère 16-pole machine with a multiple-circuit winding, each circuit would carry 100 ampères. Fig. 5 constitutes a diagrammatical representation of a 6-pole multiple circuit winding.

In selecting the precise number of conductors for two-circuit windings, and in interconnecting them, one must conform to the requirements of the formula—

$$C = ny \pm 2$$

in which

C = number of face conductors
n = „ „ poles
y = " winding pitch."

The " winding pitch," y, must be distinguished from the polar pitch τ, as it represents a different, though related, conception. If, as in the diagram shown in Fig. 4, the conductors are numbered successively from 1 to 62, the odd numbers representing upper and the even numbers lower conductors, as shown in Fig. 6, then the numbers of conductors spanned by the end connections, in this case 11 at the front (commutator) end and

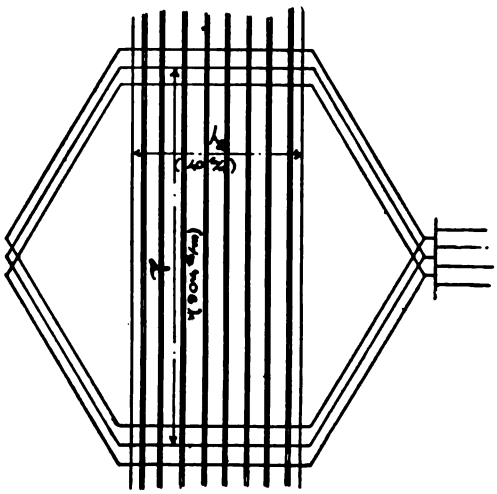

FIG. 11.—DIAGRAMMATIC DEVELOPMENT OF ARMATURE CORE AND WINDING OF 400 K.W. DYNAMO.

(λ_g = *Gross length, and* χ_n = *Net or effective length of Laminations in Armature Core.*)

9 at the back end, are the front end winding pitch, y_f and the back end winding pitch y_b respectively.

In this case,

$$y_f = 11 \text{ and } y_b = 9$$

$$y = \frac{y_f + y_b}{2} = 10$$

n, the number of poles, equals 6, and we find that a permissible total number of conductors is

$$C = 6 \times 10 \pm 2$$
$$= 62 \text{ or } 58$$

and the former number has in this case been taken.

From the nature of the mechanical design of the winding, necessitating successive connections between a top to a bottom

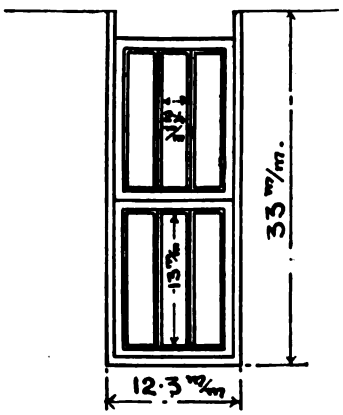

FIG. 12.—CROSS-SECTION THROUGH ARMATURE SLOT OF 400-K.W. DYNAMO.

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conductor, y_f and y_b must always both be odd. However, they may be, and often are, equal, in which case their mean value $y = \frac{y_f + y_b}{2}$ must of course also be odd. But when they are unequal (as in this case 11 and 9) their mean value, *i.e.*, the mean value of the "winding pitch," will be even.

For multiple circuit windings, the choice of values is much less restricted. The "winding pitch" y is generally taken nearly equal to $\frac{C}{n}$ y_f and y_b being respectively $y \pm 1$ and $y \mp 1$. Sometimes a value for y considerably less than $\frac{C}{n}$ is chosen for multiple circuit windings. Such windings are called "short chord" windings, and will be subsequently referred to.

Both two-circuit and multiple circuit windings may be arranged as double, triple, quadruple, etc., windings, and may then be designated as two-circuit *multiple* windings, and multiple circuit *multiple* windings. The former of these types, often denoted as the "Arnold" winding, is much used on the Continent, rarely in England, and, of recent years, practically never in America. The formulæ controlling such windings are less simple. They may be found in armature winding treatises, and will not be given here. So far as relates to the winding diagrams of Figs. 4 and 5, it merely remains to explain that each radial line may represent NOT a SINGLE conductor, but a group of two or more conductors. In Fig. 7 is shown the development of the single, three-turn coil of a 2-circuit (wave) winding, and in Fig. 8 is shown a similar development for a multiple circuit winding with three turns per coil. Such windings are, so far as location in the slot is concerned, susceptible to a number of arrangements. An arrangement frequently employed for three segments per slot is shown in Fig. 9.

Strictly speaking, the windings of the types shown in Figs. 4 and 5 should be referred to as two-circuit *single*, and multiple-circuit *single* windings respectively, to distinguish them from two-circuit *multiple* (*i.e.*, double, triple, etc.) and multiple-circuit *multiple* windings. The use of these multiple (*i.e.*, double, triple, etc.) windings is, however, so rare that, except when expressly stated to the contrary, two-circuit windings and multiple-circuit windings will, in the following, be understood to denote *single* windings.

For two-circuit windings two brushes suffice, independently of the number of poles, but as many sets of brushes as there are poles are generally preferable. For multiple-circuit windings there *must* be as many sets of brushes as there are poles, the only alternative consisting in cross-connecting the commutator, a very undesirable practice now generally abandoned.

The following example based on a standard 400 kilowatt design, to which Figs. 10, 11, and 12 refer, will serve to illustrate the process of estimating the armature resistance:

Rated output of dynamo—400 K.W.
Rated voltage—550 volts.
Rated speed—100 R.P.M.
Rated current—730 ampères.
Number of poles—8.
Type of winding—multiple-circuit.
Number of paths through winding—8.
External diameter of armature (D)—230 centimeters.

$\tau \left(= \frac{230\ \pi}{8} \right) = 91$ centimeters.

Gross length of armature core between flanges (λ_g)—40 centimeters.
Number of ventilating ducts—8.
Width of each duct—13 mm.
Per cent. insulation on core plates—10%.
Net length armature core between flanges $= \lambda_n = (40 - 8 \times 1{\cdot}3) \times {\cdot}90 = 28$ centimeters.
Mean length of one armature turn $= 3\tau + 2\lambda n = 273 + 54 = 327$ centimeters.
Total number of armature slots—264.
Number of conductors per slot—6.
Total number of face conductors—1584.
Total number of turns $= \frac{1584}{2} = 792$.
Ditto in series between brushes, $\frac{792}{8} = 99$.

Total length of conducting circuit between brushes $= 99 \times 327 = 32{,}400$ centimeters.

Cross-section one armature conductor $= 2{\cdot}4$ mm. $\times$ 13 mm. $= 0{\cdot}312$ square centimeters.

Total cross-section of winding between positive and negative brushes, $8 \times 0{\cdot}312 = 2{\cdot}50$ square centimeters.

Armature resistance at 60° Cent.—

$$\frac{32400 \times {\cdot}0000020}{2{\cdot}50} = 0{\cdot}026 \text{ ohms.}$$

It is of course a simple matter, from this result, to estimate the armature copper loss, *i.e.*, the C^2R loss. This is

$$730^2 \times 0{\cdot}026 = 13100 \text{ watts.}$$

The current density in the armature conductors is equal to

$$\frac{730{\cdot}0}{25{\cdot}0} = 292{\cdot}0 \text{ ampères per sq. centimeter.}$$

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This last figure is much lower than is at present considered desirable. Engineers have been very slow to depart from traditional constants, and this is an instance, in so far as it still represents present general practice.* For by the use of liberal armature ventilation by means of ducts amongst the core laminations, far more heat may be dissipated from the armature than was possible prior to the custom of employing these ducts so liberally. This single consideration is having the most wide-reaching effect on the proportioning of dynamos. The number of armature conductors may—so far as relates to finding space on the core for them—be increased in proportion to the increased current density employed. Many other considerations must, however, be taken into account.

Thus while the embedded portion per turn is slightly decreased, owing to the decreased total flux required, the end connections are not shortened (on the assumption of unchanged armature diameter), and the total length of one turn is but slightly decreased.

Except in so far as relates to this slight decrease in the mean length of one armature turn, the armature resistance, and thus also the armature C^2R loss, will go up as the square of the increased number of conductors, for the length of the circuit between brushes is increased simultaneously and in proportion to the decreased section.

The general result, as will subsequently appear more clearly, will be to slightly impair the efficiency at high loads, and to considerably improve the efficiency at low loads—on the whole a very desirable result. But it also affects the question of commutation, the consideration of which must, however, be deferred to a later section.

The estimation of the conductivity of the field magnet windings introduces no new considerations, and cannot, moreover, well be introduced at this point, since the whole matter of field magnet windings is intimately connected with the subject of magnetic circuit calculations.

After leaving the armature winding, the current passes, by means of the commutator and brushes, to the terminal cables. A considerable loss is encountered at the commutator. The total commutator loss is composed of two components, the C^2R loss and the friction loss. The former is very dependent upon the quality of the carbon brushes employed. Recent investigations* have demonstrated that for practical purposes the voltage drop at the brush contact is, for a given quality of brush, fairly independent of the current density, the brush pressure, and the peripheral speed of the commutator under the brush. It will be so taken in the calculations in these articles. But it varies greatly with different grades of carbon brush, and this variation may, for practical purposes, be taken as ranging from 1·2 volts drop at positive plus negative brushes for the quality of brush of lowest contact resistance, up to 2·8 volts for that of highest contact resistance. For machines with thoroughly good commutating properties, brushes approaching the lower limit would be employed in the interests of reduced commutator C^2R loss, reduced heating and improved efficiency, but for large, high-speed machines, the commutation can rarely be made too good, and brushes with the higher contact resistance must be employed. As to the current density to be allowed, this, in the interest of reduced commutator friction loss, should be high, but unless the commutation constants of the machine are excellent, high current density at the brush contacts is undesirable. Table I. conveys a rough idea of the range of values to be permitted for the current density.

TABLE I.

Volts drop at brush contacts. (pos. + neg.)	Permissible Current Density.	
	Machine of excellent commutating constants.	Machine of only moderately good commutating constants.
1·2	12	8
2·8	5	4

The brush pressure for dynamos† should be very light, not only in the interests of reduced commutator friction loss, but also because the conductivity is not materially improved by increased pressure, and the smoothness of the sliding contact and the quality of the commutation may be distinctly impaired by increased pressure. 0·1 kg.

* As a matter of fact, in this particular case, the low density was unavoidable on account of a guarantee which had been made as to full load efficiency of the machine. An improvement to the extent of several per cent. in the efficiency at medium loads, could have been obtained by the sacrifice of 1 per cent. in the full load efficiency.

* "Der Uebergangswiderstand bei Kohlenbürsten." By Dr. Ing. M. Kahn. Sammlung elektrotechnischer Vorträge, Band III., Heft 12. Enke, Stuttgart, 1902.

† For motors other considerations, such as vibration, often affect the question of suitable brush pressure.

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per square centimeter of bearing surface is a good value to endeavour to secure. A friction coefficient of 0·3 has been found fairly representative for carbon brushes on a copper commutator at average commutator speeds.

The peripheral speed of the commutator should be so low as reasonable regard for other considerations permits. A peripheral speed of less than 10 meters per second has been recommended by some designers; while instances frequently occur in designing, where 18 meters per second, and even over 20 meters per second, appears justifiable. It cannot, however, be denied that carbon brushes operate much more satisfactorily at peripheral commutator speeds of 15 meters per second and less, and that from 15 or 16 meters per second upward, it rapidly becomes imperative to secure very conservative commutating constants. With high peripheral speeds, accompanied by commutating constants in the least degree doubtful, very unsatisfactory operation is nearly inevitable, although an undesirable condition might alone be practicable.

The brush question is altogether a very puzzling one for high-speed designs. For such designs, we shall learn that it is impossible with the normal type of machine to obtain so low reactance voltage as for low-speed designs. But the reactance voltage may often be made lower the larger the commutator diameter employed, in virtue of the large number of segments thereby rendered possible. This is only the case up to the limit where a minimum reactance per segment is secured, but at high speeds, undesirable peripheral speeds at the commutator are reached well within this limit. A compromise must, therefore, be made between high reactance voltage and moderate peripheral speeds at the commutator, and *vice versâ*. At turbine speeds, some makers consider that the limit of the carbon brush has been exceeded, and they employ copper brushes, sometimes with automatic devices to shift the brush position with the load.

It is the confrontation with this state of affairs which has drawn attention to the Deri dynamo, for which it is claimed that the armature interference is so precisely neutralised by the compensating windings as to secure a fixed reversing field at all loads, thus permitting of the employment of designs with high reactance voltage, and hence smaller commutator diameters. This is, however, not the place to discuss this subject, further than relates to its bearings upon the choice of materials for the brush component of the total conducting circuit.

The method of calculating the commutator C^2R loss (or C E loss) is obvious; the total armature current is multipled into the contact voltage. Suppose in the 400 K. W. machine above considered, that brushes of a grade having 1·0 volt contact drop at the positive and again at the negative brushes (or a total of 2·0 volts drop), are employed.

Then the C^2R loss is

$$2{\cdot}0 \times 730 = 1460 \text{ watts.}$$

If these brushes are run at a current density of 6 ampères per square centimeter, there will evidently be required $\frac{730}{6} = 122$ square centimeters total contact surface of positive brushes, and 122 square centimeters total contact surface of negative brushes.

At 0·1 kg. per square centimeter, the effective pressure amounts to

$$244 \times 0{\cdot}1 \times 0{\cdot}3 = 7{\cdot}3 \text{ kilograms.}$$

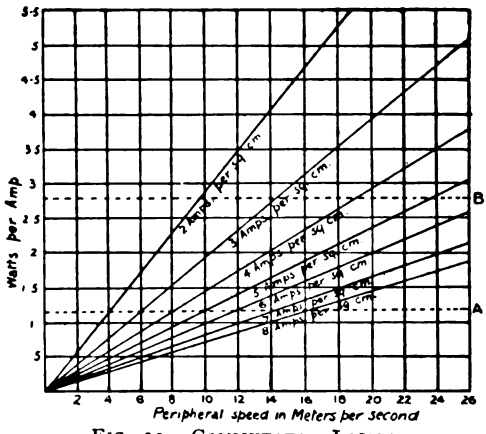

FIG. 13.—COMMUTATOR LOSSES.

For the friction loss, a brush pressure of 0·1 *kg. per square centimeter and a friction coefficient of* 0·3 *is assumed. The friction loss is derived from the sloping lines.*

A = Voltage Drop (pos. and neg.) of brushes of very low contact resistance.

B = Voltage Drop of brushes of very high contact resistance.

The commutator diameter is 165 cms., and the speed is 100 r.p.m.; the commutator peripheral speed is thus

$$8{\cdot}65 \text{ meters per second.}$$

The brush friction loss is

$7{\cdot}3 \times 8{\cdot}65 = 63$ kilogram-meters per second.

$9{\cdot}81$ watts $= 1$ kilogram-meter per second.

$\therefore$ Brush friction loss $= 63 \times 9{\cdot}81 = 620$ watts.

It is much more convenient to estimate these commutator losses by means of the

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curves of Fig. 13, in which the two dotted horizontal lines correspond to the two extreme grades of carbon brush, for which the contact voltage is 1·2 volts and 2·8 volts respectively.

Thus for the case we have just calculated, where the contact density is 6 amperes per square cm., and the peripheral speed is 8·65 meters per second, a reference to the curves shows at once a friction loss of 0·85 watts per ampere.

The C^2R loss is 2·0 watts per ampere, this corresponding to the grade of carbon brush employed, which is intermediate between A and B.

This gives for the total commutator loss

$$730 \times (0{\cdot}85 + 2{\cdot}0)$$
$$= 620 + 1460 = 2080 \text{ watts.}$$

The active length of commutator surface is measured from the point where the commutator connection from the armature winding joins the segment, to the outer end of the segment. This, for the 400 k.w. machine, is 32 centimeters.

The cylindrical radiating surface of the commutator is thus

$$\pi \times 165 \times 32 = 16700 \text{ square centimeters}$$
$$= 167, \text{ square decimeters.}$$

(Radiating surfaces are generally expressed in square decimeters.)

The watts per square decimeter of radiating surface $= 2080 \div 167 = 12{\cdot}4$.

This is an altogether unnecessarily low value, even for so low a peripheral speed. At this peripheral speed, the temperature rise would not exceed 1·2° Cent. per watt per square decimeter, or $1{\cdot}2 \times 12{\cdot}4 = 15$° Cent. rise.

It must, however, be noted that only the legitimate contact C^2R loss and the friction loss have been taken into account. There are parasitic losses at the commutator due to currents in the short circuited coils. The brushes are also often imperfectly fitted, and too much pressure is apt to be employed. Hence it is well, where practicable, to be very liberal in the commutator design. This particular design, however, is very needlessly liberal.

Copper Brushes.

At the present stage of the development of dynamo construction there is little occasion to consider copper brushes. It cannot, however, be foreseen with any certainty whether the near future will not witness a return to their use for some classes of machines.

It will suffice to state that their contact conductivity may be taken at about ten times that of carbon brushes and the friction coefficient at 0·2 as against 0·3 for carbon brushes. Thus it is evident that were it not for commutating difficulties, the use of copper brushes would be attended with a very great decrease in the commutator losses, and would permit of the employment of far less material in the commutator. This is pointed out more as an interesting fact than as in any sense an intimation that there is reason for the designer to look forward to being able to avail himself of these advantages. In low speed machines, on the one hand, the low reactance voltages practicable do not require the use of carbon brushes; and on very high speed machines, carbon brushes, although very much needed on account of the unavoidable high reactance voltages, lead, as we have seen, to serious friction difficulties.

(*To be continued.*)

Questions and Answers.

What is the value of the "winding pitch" y and of y_f and y_b in the diagram of Fig. 5? Ans. $y = 10$; $y_f = 11$; $y_b = -9$.

If the armature and face conductors shown in Figs. 10 to 12 were re-connected up for a ten-pole machine, with a ten-circuit winding, what would be suitable values to employ for y_f and y_b? Ans. $y_f = 159$; $y_b = -157$.

What would be the value of τ, the polar pitch? Ans. 72 cms.

What would be the mean length of one armature turn? Ans. 272 cms.

What would be the armature resistance at 60° Cent.? Ans. 0·0138 ohm.

If this ten-pole design were further modified by using 8 conductors per slot, instead of 6, as shown in Fig. 12, each conductor then measuring (bare) 1·7 mm. × 13 mm., what would be the resistance of the winding at 60° Cent.? Ans. 0·026 ohm.

What would be the value of the "winding pitches"? Ans. $y_f = 211$; $y_b = -209$.

Irrespective of the desirability of such a winding (it would *not* be suitable) for this machine, would the total number of conductors by this last arrangement with 8 conductors per slot, permit of the use of a two-circuit single winding for 10 poles? Ans. Yes.

If so, what would be the value of the "winding pitch"? Ans. $y = 211$.

Could a two-circuit single winding have been used with *six* conductors per slot and ten poles? — Ans. No. With eight poles? — Ans. No.

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ON THE DIAGRAMMATIC ILLUSTRATION OF CLASS LECTURES.

A Paper for all kinds of Teachers.

By WILFRID J. LINEHAM, M.I.C.E., M.I.M.E., M.I.E.E., Head of Engineering Dept., Goldsmiths' Institute.

PART I.

AT the present time there are about three different modes of illustrating class lectures, and it is the object of these papers to consider in some detail how far each method may be used with advantage, as well as to discuss the various ways in which each system

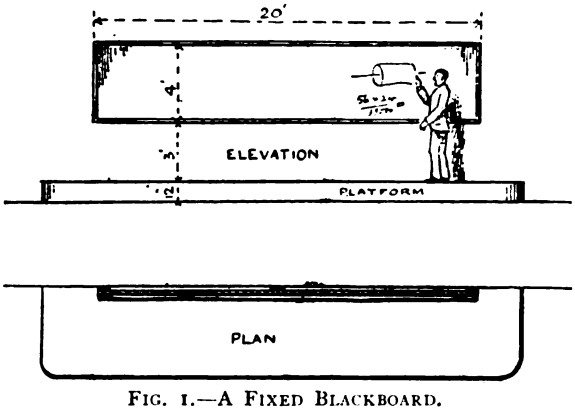

FIG. 1.—A FIXED BLACKBOARD.

may be carried out. The methods to which I refer are those of the blackboard, the large paper diagram, and the lantern slide. Just as the casual observer fancies that the introduction of a new mechanical power will cause all the old power producers to become necessarily obsolete, so there are teachers who have imagined that the diagram would entirely supersede the blackboard, and the lantern slide in turn the blackboard and diagram both. I need hardly explain to veterans that long experience has only served to impress upon us the fact of our blessedness in having the choice of all three systems, according to circumstances, while never encouraging us to delete any one of them; so it will be worth while here to contrast the systems one with another, so that we may distinguish the special functions of each.

The blackboard is probably the oldest of all the three, though the diagram may possibly have existed as long, perhaps even longer. It is very difficult to say when the blackboard was first introduced, but I do not remember ever to have seen one illustrated in a very old picture. We have, however, one clue to its age, for Mr. Cockerell, R.A., appears to have been instrumental in bringing the method of illustration before the Committee of the first Government School of Design at Somerset House in 1837, mentioning it as being much used in French Schools of Art by the students themselves, and speaking quaintly of "white chalk upon a blackboard." I think the blackboard will always be a favourite with real live teachers, for all such men will tell you that you might take away diagram or slide any day you liked, if only you left them the dear old blackboard. It is not easy to explain in words the immense help to teaching that it is to have a piece of chalk in the hand and a good *black* board at one's side, but perhaps it may be due to the wonderfully apt way in which the chalk translates the teacher's nascent thoughts into pictorial language on the instant, and

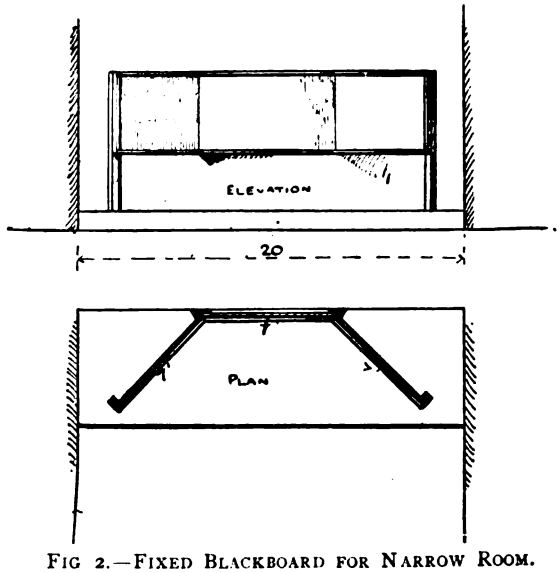

FIG 2.—FIXED BLACKBOARD FOR NARROW ROOM.

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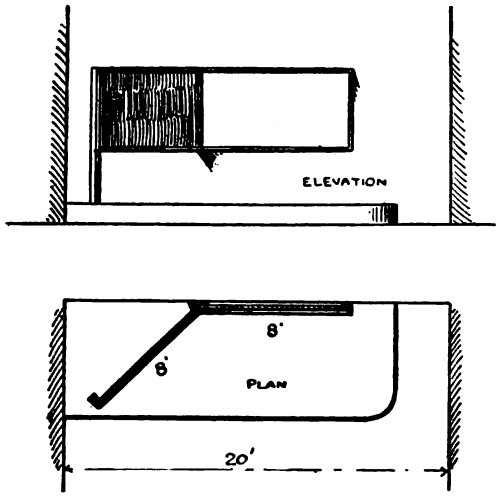

FIG. 3.—FIXED BLACKBOARD: AN ALTERNATIVE.

permits the free use both of hand and tongue at the same time. So attractive is chalk for illustration, that even with a small class it is often preferred to paper, while some mathematicians are said to work out their solitary investigations by the aid of a private board, under the belief that in that way their thoughts flow more easily than they would with pencil and paper.

If we were all born with the ability to draw freely, quickly, and proportionately, the functions of the blackboard would seriously interfere with those of the paper diagram. Such ability is at once a very great pleasure and a magnificent help to blackboard teaching; but observation shows, alas, that the skill for rapid free-hand drawing is confined to very few, not perhaps to more than one per cent. I have myself had only two such teachers, men who found it no hardship, but an actual pleasure, to chalk out the most complicated machine, or building construction figures for class use each evening. It always appeared to me a crime to be compelled to remove these pictures, and I have often tried, though without success, to induce the teachers to make their diagrams on paper, by a method to be described in a succeeding number, in order that their labours might be preserved. Leaving out of account, however, such brilliant men as I have just mentioned, it is pretty clear that the principal uses of the blackboard are to permit us to write out mathematical formulæ and calculations, to sketch out simple plans and elevations, and to plot out curve diagrams on a board marked with squares.

More difficult pictures must be treated by the diagram method. Some people rush to diagrams because they think they can always buy sets to illustrate the subject in hand; but I regret to say they will be doomed to disappointment, for very little help can be obtained from published diagrams. I cannot tell the true reason for this, but there certainly are almost no large printed diagrams to be had in England; and I doubt the fault is six of the teacher and half-a-dozen of the publisher. The latter has been so badly supported when he *has* put out a good set that he has not been encouraged to repeat the experiment, while, on the other hand, the greater number of the diagram sets which have been offered are either now obsolete or are too small in size. The fact is, that diagram printing requires very large lithographic stones, which are a source of considerable expense to the publisher. Whatever the cause of this dearth of diagrams, it is pretty evident that every teacher who wishes to use them will have to make up his mind, at least for the present, to draw them out himself, and I need hardly say, the process is somewhat lengthy and laborious, so that only fairly complicated examples should be thus treated. But I shall have more to say on this matter in a later number, when I hope to show some

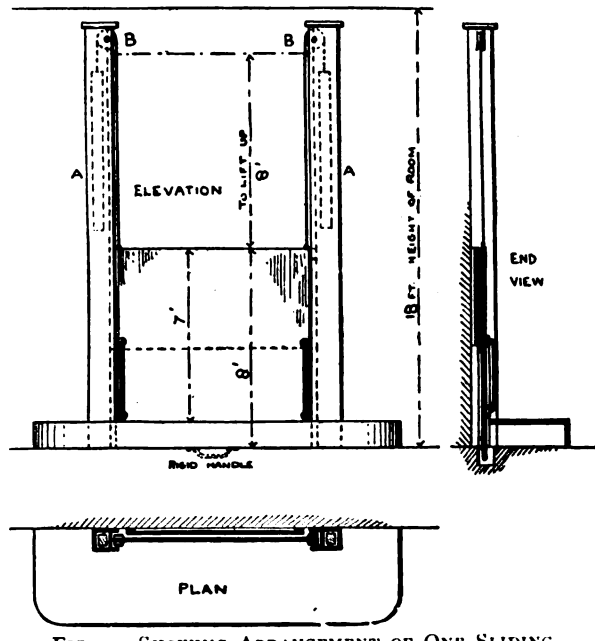

FIG. 4.—SHOWING ARRANGEMENT OF ONE SLIDING AND ONE FIXED BOARD.

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schemes for decreasing the labour of diagram making. There are yet some other faults connected with diagrams, for even if the initial expense and labour be granted, there is the storing to consider. I know no method of keeping diagrams which does not more or less deteriorate them, but the advantages of the diagram *per se* are so great that much disadvantage may be borne. What can be finer than a good display of diagrams through the whole of the time of a lecture, stimulating the student, as they do, to make good notes, both before, and, if allowed to do so, after the class, while so forcing themselves upon his attention during the whole of the class time as to burn themselves into his brain —at least, so the teacher hopes? Nothing can touch the diagram in this its superb "staying" quality. The chalk must be continually wiped off the board, and the slide must leave the screen, but the diagram remains not only for the lecture, but is often left hanging for days; while some diagrams, especially those which we desire the student to commit to memory, may remain permanently displayed, so as to "make the wall talk."

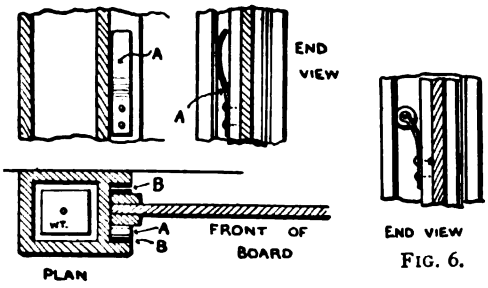

FIG. 5 —SPRING STEADIMENT FOR SLIDING BLACKBOARD.

FIG. 6.

It is when we come to the highly-complicated drawing, or the shaded perspective picture, that we find the limit of the paper diagram, however; and then we must have recourse to the most useful and beautiful assistant the lecturer ever had. We all know it is impossible to speak too highly of the lantern slide; even those of us to whom it has become excessively common, on account of its every-day use, may well pause at times to think of its incalculable advantages. In our youth the "magic" lantern was a thing to jest at, or, at least, was a mere amusement for a Christmas party, for we had then no conception of what photography would accomplish. It is important to notice, however, that just what the lantern does is quite different from what the board and diagram perform. It does not permit the picture to grow before the student's eyes as with chalk, nor does it run in such perfect harness with the teacher; and the slide is rarely allowed to remain long upon the screen. If even it be so allowed, the student is so bewildered by the complication and the dim religious light that he has to be severely urged before he will make good notes from it; but as a means of getting in a large quantity of extra illustration with a minimum of difficulty it stands unrivalled. Non-permanence it, of course, shares with the blackboard, but that is unavoidable in both cases; it beats the blackboard, however, in one thing—the picture can be returned to the screen after having been rubbed out.

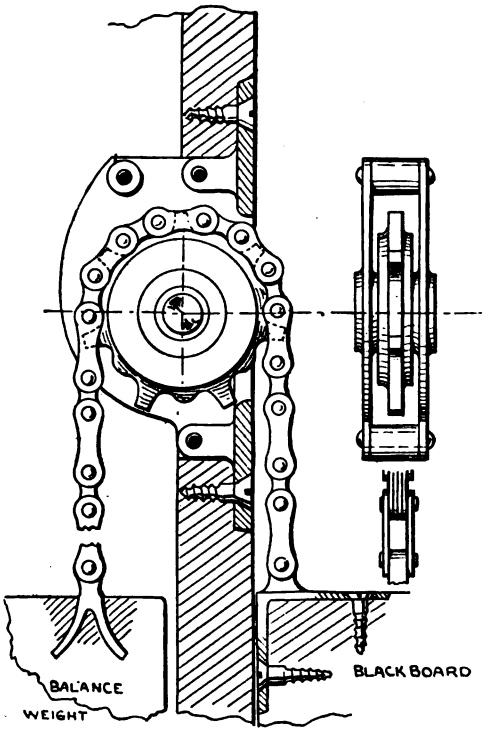

FIG. 7.—CHAIN PULLEY FOR SLIDING BLACKBOARD.

To sum up then, we may say that the blackboard gives wonderful facility for simpler work, the lantern a facility of another kind regarding complicated subjects, and the diagram the charm and use of permanence; each method of illustration has its own individual field, and that lecture is best illustrated which combines all the three methods. So much by way of introduction.

The Blackboard

We have now to consider the older method in greater detail; and first let us

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take the board itself, its construction, finish, and mounting. The most important requirement in blackboard construction is undoubtedly a large amount of surface or area, and this can be obtained in two or three different ways. The board rigged on an easel is, perhaps, the very worst arrangement that could be suggested, for although it can be freely moved from place to place, it is a most shaky construction and gives much worry to the teacher in the course of his work; and it is impossible to provide the necessary area without a number of easels. Neither is the blackboard on wheels a much better contrivance. If loose blackboards are to be adopted, they are much better hung on walls, and should generally be tilted forward, as pictures sometimes are, so as to reflect the direct light upon the floor and avoid the "shiny" effect. Most class-rooms, however, can be supplied with permanent boards, and it is this kind of board I desire especially to consider.

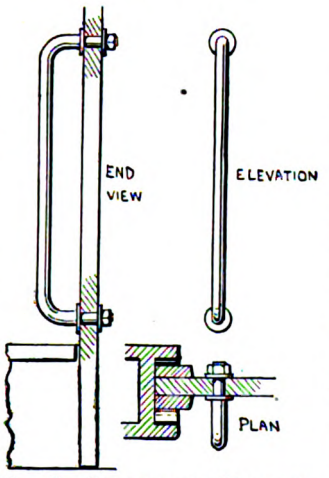

FIG. 8.—BLACKBOARD HANDLES.

A person of average height cannot manage a greater vertical reach than 7 ft., and it is rare that the student can see the bottom of the board if it be less than 3 ft. from the ground. These considerations at once establish the vertical dimensions of a fixed board, and as 4 ft. is not high, the large area we require can only be obtained by horizontal length, which should therefore be as great as the room will practically permit; but I should think no teacher would care to accept much less than 20 ft. wide by 4 ft. high—the proportions illustrated in Fig. 1. Now very few rooms can stand a blackboard 20 ft. wide, but something can often be done to meet even this case. Look at Fig. 2, where three 7-ft. boards are arranged in a room of 20 ft. width, a suggestion which at once introduces the subject of angle. Most teachers find it difficult to face students while chalking on the blackboard, and yet it is fatal to success if the teacher "talks into the board." The most pleasant angle is one of about 45 degrees, and when fixed boards are adopted I prefer this angle or thereabouts, dispensing with the right-hand board and making the arrangement shown in Fig. 3. The space actually taken up in the room is really not larger than in Fig. 1, for a platform is always required; and the convenience of the boards set in this manner is very great indeed.

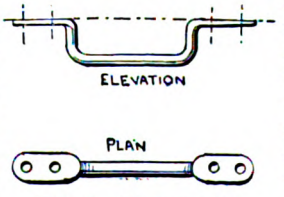

FIG. 9.—BLACKBOARD HANDLES.

Larger area may be obtained by the use of boards which can be moved out of the way in some manner, and of these we shall first consider those that slide vertically. Unless several precautions are observed in building this class of board, much difficulty and worry will follow in its use, so that the user will long for the fixed board again. There is no doubt, however, that the sliding board is a very valuable contrivance when properly constructed, for a pair of superposed sliding boards may be easily made to give four times the area of a fixed board without occupying a greater width of wall space. In Fig. 4 I have shown one fixed board, and a sliding board in front of it. When the latter is lifted to its highest position it will have been raised 8 ft. from the ground, and the total board height will then be 12 ft. in a continuous piece, or three times that of a fixed board. If the hinder board were also made to slide we could add another 4 ft. to the 8 ft. already mentioned, but as all this area could not be seen at once, the advantage would not be so great, so the board shown in Fig. 4 is probably as good an arrangement as one could have. Put three of these sliding boards in line at the end of a room, and the most active mathematician would be happy; and none would have reason to complain but the boy who had the cleaning to do after the lecture.

As with many other constructions of a practical nature, the most important matters are the actual details. A sliding board, however well made, soon becomes loose, and both teachers and students are disturbed by the continuous rattle as the chalk flies over the surface. To overcome this difficulty I have inserted flat springs, as at AA (Fig. 5), in the front edge of the groove in which the board slides. Two such springs on each side of the board are sufficient for stability, and they should have the least possible

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strength beyond that necessary to take up the shake or back-lash. The sliding plates BB I have made of iron, but if they can be afforded are better of brass, not being really expensive then. Those who desire still less frictional resistance would do well to try the device shown in Fig. 6, where rollers are attached to stiffer springs. The sash-weights AA, Fig. 4, are a fruitful source of trouble when they are not made to accurately balance the weight of the sliding board, which is a matter that should be very carefully looked into, otherwise there is more difficulty in moving the board one way than the other, which is unpleasant; and the pulleys BB are also of very great importance. They should run as freely as it is possible to make them. It is of no use to put in small rough cast-iron things on iron pins. Large pulleys of six inches diameter, when carefully turned and bushed with brass, run very freely if the boards are not too long; but I am sure the best pulleys are those with roller bearings, which can be obtained of the Gandy Belt Company. I have recently experimented with the form of pulley shown in Fig. 7, known as Rhodes' Patent, and have been much pleased with its performance. There are two advantages to be obtained in its use: the fact that it is actuated by a chain and sprocket teeth compels it to turn *in its bearing* and thus prevents the extra resistance of a scraping rope, and there is no stiffness to contend with as in the case of ropes, the chain wrapping round its pulley quite freely. Although these pulleys are not at present made larger than three inches in diameter, reckoned at chain centres, yet as they are made in gun-metal they run very sweetly, the blackboard for which I have used them being eight feet wide, six feet high, and very heavy.

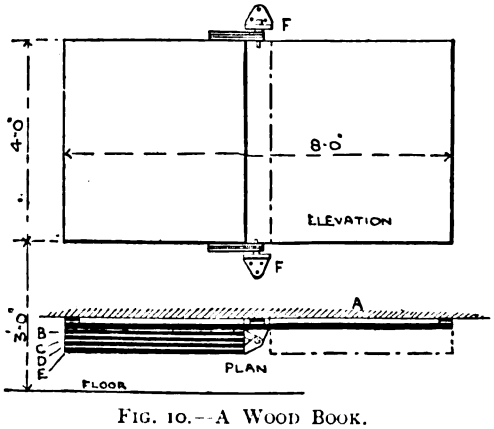

FIG. 10.—A WOOD BOOK.

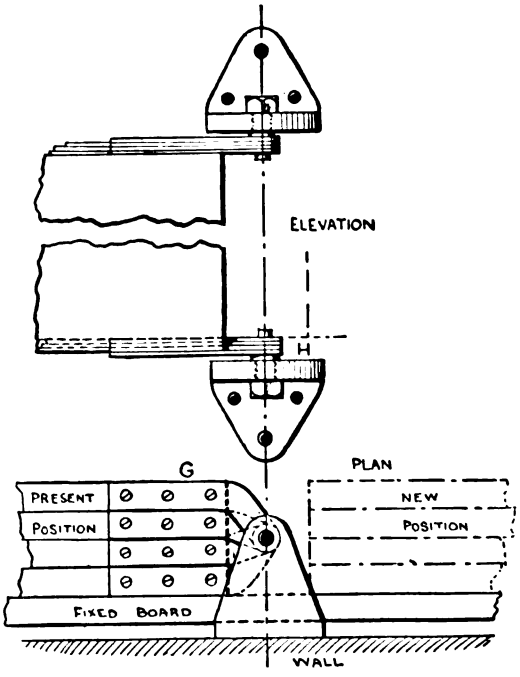

FIG. 11.—HINGE DETAILS FOR WOOD BOOK.

The mode of raising and lowering the board must not be forgotten. It is a matter of regret that the centre portion is an inconvenient spot for the fixing of handles, but if the sliding grooves are a reasonable fit, the handles may be put at the sides of the board and yet serve to actuate it with a good degree of satisfaction. The kind of handle I advise—shewn in Fig. 8—is placed as near the board side as is possible without chafing the hands on the slide, and reaches within two inches of the floor while extending to a height of 3 ft. when the board is lowered. It is made out of $\frac{5}{8}$-in. round iron turned down to $\frac{1}{2}$ in. before being bent, while washers on both sides receive the pressure due to tightening the nut. One of these handles is placed on each side of the board, and at the bottom another handle, Fig. 9, is fixed for the purpose of reaching the board when raised to its full height, sinking into a floor recess when at lowest position.

There is yet one more method of obtaining a moving blackboard, to which I have given the title of the "wood book." One board A, Fig. 10, is fixed to the wall, while four boards B C D E are supported upon hinges FF, and thus with a wall board 8 ft. wide as background, we shall have multiplied our space (in the case shown) by five. The contrivance is really very easily built up. Four plates GG,

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Fig. 11, are fitted to the board edges at such angles that all may meet on a fixed pin H, carried on a bracket standing from the wall at such a distance that the centre of rotation is in line with the mid board; and thus all the boards are symmetrical and may be rotated to right or left. I believe this apparatus needs only to be known to be highly appreciated.

It is worth while noticing here the solid geometry blackboard made by the North of England School Furnishing Company, and seen in Fig. 12. It is of immense aid in the teaching of projection. Being of the book form already described, its parts can be turned to any angle upon a horizontal axis, but, what is more important, the hinge bands may be clamped by the screws AA at the angle preferred. We thus have excellent "planes of projection" before us, upon which solid objects may be placed and put into plan and elevation with the greatest ease. It will be noticed that the two opposite boards are always rigidly connected, so that balance is preserved, while there are four "quadrants" for the teacher's operations.

Before leaving the subject of construction proper I hope to be allowed to present the reader with two further suggestions, which, so far as I know, have not been practically adopted. Fig. 13 shows how a floor may be built so as to permit the blackboard to slide into a cellar below and thus give a much greater height of chalking area. The idea is adopted from the lofts used by scene painters. In the case of an upper class room an attic would be used for storage instead of a cellar, and in both cases strong cords would have to be attached for raising and lowering, as in the case of some lifts, for the board itself would not always be reachable. The second suggestion, Fig. 14, is copied from the diorama. I fear it is not quite so practicable on account of the difficulty of finding suitable material, which would have to be painted canvas of fine grain, lying against a backing board which supplies the necessary firmness.

Having now fully explained the methods of mounting the blackboard, we have to investigate what, I regret to say, is a very vexed subject, the kind of surface which we ought to have to most easily receive the chalk, from which the chalk can be most easily removed, and which will preserve a dead black surface at all times. Our difficulties have commenced. The oldest method has been to paint the well-planed wooden surface with black paint. First a coat of lead paint to fill up all cracks, and, after rubbing down well, another of ordinary black paint, which is again rubbed. Lastly, a coat of specially prepared black designed to give a matt surface which is neither too rough nor too smooth, but simply perfect—and "there's the rub." This finishing paint will either make or mar a blackboard. I give the following recipe as having proved satisfactory so far as I have tried it, but I must caution

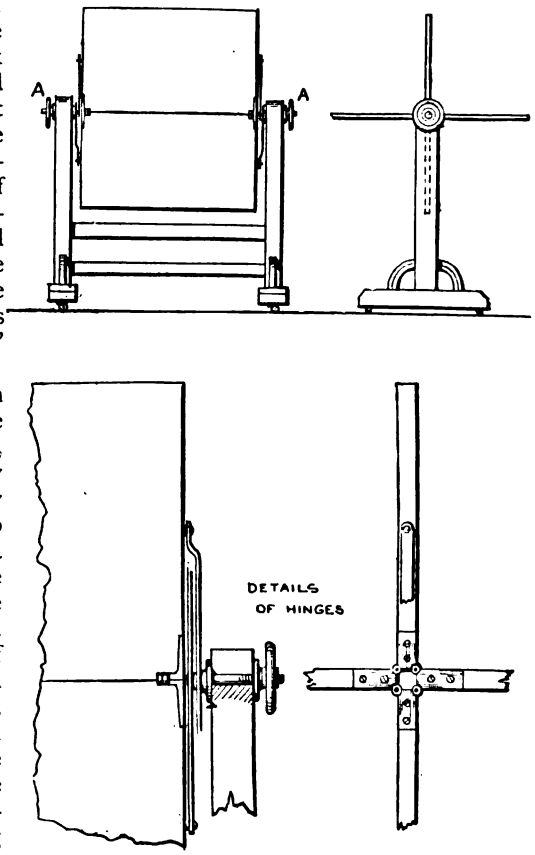

FIG. 12.—BLACKBOARD FOR TEACHING PROJECTION.

users regarding the emery powder. It must be the very finest obtainable, and the mixing of it with the paint should be thorough and continual during the actual operation of painting. The amount of emery used can vary slightly, say to twice the amount stated.

RECIPE FOR A BLACKBOARD PAINT.

Dissolve one pound of shellac in one gallon of methylated spirit (95%), and add half-a-pound of best ivory black, 2½ ounces

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of *finest* flour emery, and a quarter-pound of ultramarine blue. Mix and put in stoppered bottles. Shake well when using.

But, do what you will, it is excessively difficult to make a really satisfactory surface of black paint on wood, that will last for a long period without either becoming shiny or chalky, and so it is not surprising that teachers have sought for other means of obtaining the desired result. Slate has been used with success, but must be rubbed over with black ink from time to time. It is also heavy for sliding boards if made thick enough for strength. Ground glass is mentioned as an ideal surface by those who have used it, but cost and danger of breakage are evidently against it. If, again, white glass be used, a blackboard placed behind it comes out only a light gray in front: an objection which has been obviated in some places by making the glass itself of black material, which must be fearfully expensive.

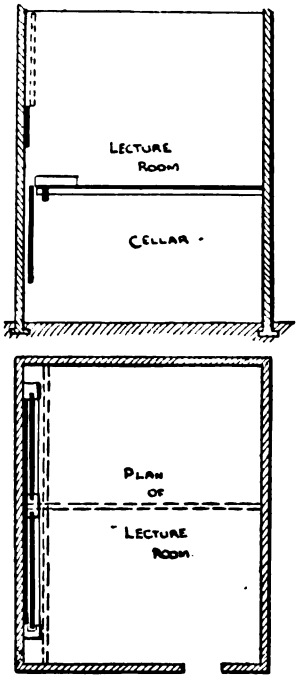

FIG. 13.—SUGGESTED BLACKBOARDS.

The mention of all the previous surfaces is only a preliminary to that surface the secret of which I am about to impart. This surface is, so far as I know, the invention of Professor Barrett, of the Royal College of Science, Dublin, and I do not believe anyone else had used it before him. The invention is by no means in its experimental stage, for there have been boards in Dublin in use for fifteen years which are still in a highly satisfactory condition. It is nothing more nor less than the covering of the blackboard, or rather a simple wood backing, with linoleum of a "self" colour, the variety known as "cork lino," I believe. It must have no paint upon it excepting the thin watery black that is to prepare it for use. Those who run principally after cheapness will perhaps find themselves somewhat disappointed, for a pretty good surface of wood must be provided before the lino is laid on. Supposing this backing provided, you must first hang up the lino by tacking it loosely, and permit it to stay so for two or three weeks, so as to "unset" and get accustomed to the atmospheric conditions. At the end of that time it is to be fastened to the board with stout glue, or better still, glue and size mixed, and the edges should be tacked down thoroughly all round, being preferably afterwards covered with a wooden bead. The lino can be procured at from 2*s.* 6*d.* to 3*s.* per square yard, and although it adds to the cost of construction, the latter may be somewhat reduced in the case of a fixed board, as follows: Nail slate battens to the wall for a frame or border, and smooth the enclosed surface with strong plaster or cement, to a level with the battens. When dry, size the wall for a first coat, and afterwards stick the lino with the usual glue mixture, nailing and beading as before. I daresay this arrangement would come out cheapest; it would certainly be the most satisfactory procurable. The lino has now to be blacked, which may be done by a paint made to this recipe:

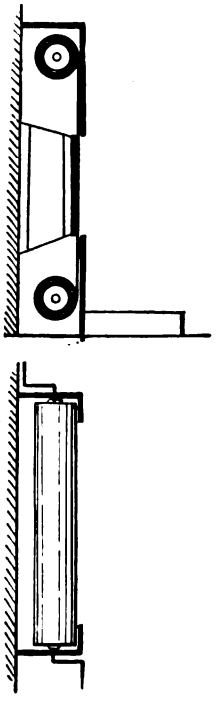

FIG. 14.—SUGGESTED BLACKBOARDS.

BLACK PAINT FOR A LINO-BOARD.

½ lb. of shellac.
One gallon methylated spirit.
¼ lb. best ivory black.
2 oz. ultramarine.

The surface is extremely pleasant, taking the chalk freely while permitting its easy and complete removal. Besides, the black paint can be re-applied at times if a bottle of it be kept handy, and we have no such variable degree of roughness as with wood boards and emery paint.

THE DUSTER.

The duster is a barbarous tool for the removal of chalk from a blackboard; but

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like the lead pencil in wood, it seems as though we shall always have it with us. The duster should be used *dry*, and be shaken out thoroughly every day, but do as you will it is messy, and is best kept in a box near the blackboard, so as not to interfere with the serenity of the lecture table. I once worked with a blackboard cleaner that aimed at being a cut above the duster. It is shown in Fig. 15, and consisted of a specially-shaped block of wood, held by the hand, to the face of which was glued a piece of thick felt. This construction was too resistant and unaccommodating, and if I were using such an apparatus again, I should propose to make it as indicated in the drawing, viz., I should cover a packing of horse-hair with thin canvas and a soft plushette, thus obtaining elasticity and softness. The block should be beaten out daily.

It is well to wash the board with *clean* water pretty often, a large sponge being the best assistance for this purpose, if well wrung out. The lecturer might also have a damping apparatus, built on the plan of the chalk-cleaner just mentioned. It would consist of a block of wood of the shape already described, but having a rectangular piece of sponge fastened thereon by brass wire, as in Fig. 16. The wire is passed through the sponge and round tacks in the side of the block. This sponge, being small and not easily cleaned, should never be used for the daily washing, but should only serve as an adjunct to teaching.

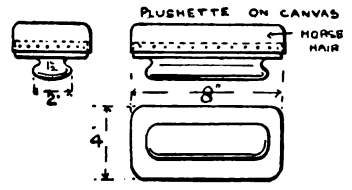

FIG. 15.

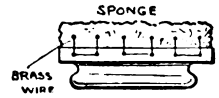

FIG. 16.

BLACKBOARD CLEAVERS.

THE CHALK.

I wish I could say a great deal about the chalk, for there is much improvement needed in this direction. It is about twenty years since I have used really good chalk, a remnant of which lies on the table as I write. The pencils then made were apparently cut from natural blocks, and were of about $\frac{5}{16}$ in. square in cross-section. That they were made of natural chalk, without gum, there was no doubt, for we often produced carbonic oxide gas from them in the laboratory. Just about that time the new and artificially made conically moulded pencils were introduced, and we knew they were artificial, because we could no longer produce gas from them on account of the gum binding material. The difference in working on the black board was not at first noticed, but I regret to say that in later years they have so deteriorated as to try one's temper most severely. A good chalk should be strong enough to hold, and yet be both soft and even in working. Such chalks, as far as my experience goes, are impossible to obtain at present, and one longs for the old natural chalk, which is now unprocurable. A holder is also a good thing to have. It should not be long or heavy, and a tube of papier maché or reed seems desirable, so long as the pencil can be held in place and be gradually advanced.

One word more, on the use of chalk for drawing on the board. Never draw the picture firmly from the start, unless it be of very simple form, but sketch in roughly, rapidly, and lightly, to get the proportion correctly. That done, the drawing may be lined-in with a firm and steady hand. This is not only the best method of producing a good drawing, but it is an instructive exercise for the student, who should be similarly taught to make his sketches, viz., by a rough pencil outline at the first, and the use of the pen afterwards for lining-in only.

We must next consider the production, hanging, and storing of lecture diagrams.

(*To be continued.*)

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TECHNICAL EDUCATION AND THE MAINTENANCE OF OUR INDUSTRIAL AND COMMERCIAL POSITION.

By PROFESSOR WERTHEIMER, B.Sc., B.A., Principal of the Merchant Venturers' Technical College, Bristol.

PART I.

WHILE in this country we provide—at least, in our great towns—splendid buildings for our public elementary Schools and adequate funds for their maintenance, the sums we devote to higher forms of education are small when compared with those expended by our leading industrial competitors. So far our Government has been content to point with pride to the hundreds of thousands of children receiving their education in the State Elementary day schools and to the tens of thousands of adults who are receiving an education, for the most part only a little less elementary, in the numerous evening classes which the national exchequer supports. The public purse has been rigidly closed, or at best, very slightly opened, when it has been a question of defraying anything beyond this.

It may, however, be said that we have commenced our educational work at the right end, and that while we are now in some respects on a par educationally with Germany as she was some twenty years ago, we are, in others, slightly in advance of her. The question for the nation is whether we are, or are not, prepared to regard national education as the Germans and Americans regard it, and to treat it as by no means the least important branch of the nation's equipment for defence and offence in the industrial war for that supremacy in trade which we held so long, but which now stands in grave danger.

Our Attitude toward Technical Education.

In order to keep open for our trade and commerce existing doors, and, where necessary, to open new ones, we very wisely maintain our Army and Navy in as efficient a condition as is possible, considering the defective character of the technical education of those responsible for the welfare of the two services. But it has hardly yet dawned on our rulers that it is of quite equal importance that the men engaged in making and distributing British goods should have an intellectual equipment as good and as suitable for its purpose as that provided for their competitors.

The first need of this country is that our Secondary Education should be put on a proper basis; and it may be hoped that the new Education Committees which have recently begun their work will do much in this direction. But it is to be regretted that the Government has thrown the whole responsibility for the work on these local bodies, without laying down any principles for their guidance, beyond the requirement that they are to "consult" the Board of Education before taking action; for there are many points in this connection which could be dealt with much more satisfactorily by a central body like the Board of Education than by a Local Authority, such as the council of a county or a borough.

Secondary Education.

Take, for instance, the case of the fairly numerous small, badly endowed and imperfectly equipped grammar schools which are to be found in some of the counties, even within comparatively short distances of one another. There are some such schools with less than thirty pupils taught by only two masters, or, in some cases, by a single master who has to deal with a school composed of boys varying from nine to sixteen years of age. A central authority would almost certainly group together such schools, forming one really good school of a reasonable size in a central position, and using the small local endowments to provide special boarding scholarships for the children of the localities in which the grammar schools stand; but it is doubtful whether a local education committee will always feel itself strong enough to take such action in defiance of opposition from the villages which might dislike to lose a "grammar school," even though they received in exchange a much better education for their children than the old school gave.

The Grouping of Grammar Schools.

On the other hand there are many country grammar schools of reasonable size which

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are at present doing the best work possible with the limited funds at their disposal, though often hampered by the fact that their pious founder knew of no kind of knowledge that was not enshrined in mathematics, Latin or Greek, and so condemned the twentieth century pupils of his school to spend laborious hours on one or both of these languages. The result of this is that too few of these country grammar schools provide a modern education suitable to the needs of the great majority of their pupils. It is a fact that such schools send every now and again one or two of their best boys to Oxford or Cambridge, but is it right to sacrifice nearly all the remaining boys in the schools in order that these few may receive the particular kind of preparation which the ancient Universities demand? For it must be remembered that the rank and file of the boys in such schools hardly ever obtain a knowledge of the classics sufficient to enable them to enjoy their literary flavour; indeed, few of them ever open a Latin or Greek book when once their school days come to an end. It is true that their minds have been more or less disciplined by these classical studies, but most competent judges, acquainted with *both* methods of education, recognise that an equally good mental training can be provided through the medium of modern languages and natural science, with the result that the pupils' brains are sharpened by the study of subjects which are useful to them in their after lives, and in which many of them continue to take intellectual interest when their school careers are finished.

Technics and Classics.

Let us suppose, however, that the Local Authorities rise to their responsibilities and provide in all parts of the country an adequate number of efficient Secondary Schools of different types. Some of these will provide for the needs of those who can spare time and money for a classical training, to which they may at a later period add a sound knowledge of modern languages and the main facts of natural science, without which they can be but incomplete men. But the greater part must be designed to meet the requirements of those whose secondary education cannot be extended over a very long period; in these schools classics must make way for modern languages taught so as to enable the pupil to speak with fair fluency as well as to gain such a sound knowledge of the languages as shall enable him in after-life not merely to study standard authors, but also to follow current literature. It is in these schools that the men and women who are to take the foremost subordinate posts, and not a few of the principal ones, in trade and commerce will, for the most part, be taught.

On such a foundation of good secondary education a satisfactory system of technical education might be grounded, and we must next take a rapid survey of the facilities for this at present offered in this country. These consist mainly of classes for *adult* students held (*a*) in the daytime, or (*b*) in the evening; for, of course, we must not count many of the day departments of our so-called Technical Schools, which are in reality nothing but modern schools for boys and girls, and, in so far as they are attempting to give technical training, are doing so at the expense of the sound secondary education which ought to be given to pupils so young as those who attend them. It is difficult to lay down an absolute rule as to the age at which technical education ought to commence; in Germany and America it does not begin, except in very rare cases, before eighteen, and this arrangement is no doubt a wise one, as it secures a sound general education before any specialisation starts. In England there are a few institutions where the minimum age is above sixteen. Most of our University and Technical Colleges admit students at that age, and in some of them students may enter at fifteen.

The Foundation of Technical Education.

This system cannot, of course, be speedily altered, but in all the best institutions giving technical education, an effort is being made to raise slowly the standard of age and requirements at entry. Still our entrance examinations are at present for the most part of an exceedingly feeble character, and compare most unfavourably with those required from German or American students.

Nothwithstanding the very low age of entry to the Day Classes of Technical Institutions in this country and the almost entire absence of any entrance examinations worthy of serious consideration, the number of day students in such institutions in the United Kingdom is very much smaller than is the case in either Germany or the United States. For in 1901 there were in all our technical institutions giving technical education in the daytime—including Universities and University Colleges—fewer than 4,000 individual day students of technology, and this number was obtained only by counting every student in such institutions who was

Age of Students.

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above the age of fifteen. For the German Empire the corresponding number was only a little short of 15,000.

When it is remembered that the German students are on an average at least two years older than ours, and that they have, for the most part, passed satisfactorily through a nine years' course of training in a secondary school, while our students in many cases have commenced their studies after a very meagre preparation, it will readily be understood how very poor, both in quantity and quality, is the preliminary training of those who are to become our captains of industry, when compared to that given to the same class of persons in Germany.

Our readers will naturally suppose, however, that since our students begin their studies so early and with such a poor foundation, they make up for this by prolonging them for a period longer than that which is usual in the case of German and American students; but the contrary is, unfortunately, the case. In Germany and America, few such students take a course of less than three years' duration, while many of them pursue their studies for four years; in the United Kingdom, on the other hand, few of our students pursue their studies for more than two years, with the result that when we compare the number of third and fourth-year students in this country and abroad, we find an even worse state of affairs than when the total number of students only is considered. For in 1901 there were in the whole of the United Kingdom about 400 third or fourth-year students taking complete day courses—*e.g.*, in Engineering; while in a SINGLE German institution — the Charlottenburg Technical High School at Berlin—there were more third and fourth-year students of this subject than ALL our Universities and Colleges put together could show. None of the German third and fourth-year students were under twenty, while many of ours were as young as seventeen.

Period of Studentship

It is easy to see that there must be grave reasons for the great disparity illustrated by the facts just mentioned; the most important of these reasons will now be stated.

The American or German employer believes in the value of technical training; he prefers to take into his works a young man at what our manufacturers would regard as the comparatively late age of twenty-two, provided the recruit has a really sound knowledge of the sciences underlying the employer's industry, and is able to bring well-trained brains into the work. Anyone who doubts this has only to read the exhaustive report on the subject issued by Mr. Carroll D. Wright, the Commissioner of Labour for the United States of America in the year 1902, and entitled "Trade and Education." Or, if further evidence be needed, the fact may be mentioned that in one of the leading American technical institutions, the Massachusetts Institute of Technology at Boston, some three hundred students, as a rule, finish their training each year at the age of twenty-two. So great is the demand for them, that there are more applications for those who have completed the four years' course than the Institute is able to supply.

The Value of Technical Training

In this country, on the other hand, the great manufacturers for the most part prefer to take into their works young apprentices who pay premiums, and in return obtain greater or less opportunities of seeing practical work on a commercial scale. Frequently these apprentices have little, if any, technical training, and are consequently, as a rule, less capable of suggesting and carrying out improvements than Americans or Germans of equal brain power.

Premium Apprentices

No doubt part of the contempt for, and neglect of, technical education in this country arises from the fact that many of our leading manufacturers are "self-made" men who have had but little education themselves, and have, in spite of this, or, as some of them unfortunately believe, on account of this, risen by their natural abilities to positions of eminence. Others have been trained in our great public schools, where, as one of the greatest admirers of these schools admits, it is by no means always considered good form to acquire knowledge, and where the study of science is not infrequently regarded as more worthy of toleration than encouragement.

The earlier products of our Technical Colleges were also in many instances so proud of their theoretical knowledge that they were unable to recognise the very many points in regard to which the practical man, with his rule-of-thumb methods, was their superior. As a result, they offended manufacturers and their foremen by a bumptiousness directly proportional to the amount of their ignorance of practical commercial methods. Fortunately this is fast becoming a thing of the past; professors in our Technical Colleges now take particular care to impress on their students that the "practical" man deserves their respect, and that it is only by becoming prac-

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tical men themselves that they can make their theoretical knowledge and laboratory experience of value in the industries with which they are concerned.

Besides the unwillingness of the average British manufacturer to employ highly trained assistants, we have also to cope with the drawback that the average British parent, unlike his German or American cousin, does not himself believe in education. He is inclined to say that the sooner his boy or girl begins his or her business career, the better it will be for all parties concerned; on the other hand, the German or American parent is willing to make great sacrifices in order to give his son or daughter absolutely the best training for his or her work in life which it is possible to obtain. For this purpose the comparatively poor German not merely taxes himself heavily, but also maintains his children for many years longer than is the case in this country. He finds his reward in the enormous increase in the trade and prosperity of Germany which has taken place in recent years, and which is, no doubt, to a large extent due to the great improvements in technical and commercial education in that country.

Popular Opinion

Our Government naturally reflects the opinions of the average British parent, and neither Liberal nor Conservative Administrations have shown any desire to take seriously in hand the problem of the provision of higher technical and commercial education in this country. Such provision would involve not merely a large increase in the amounts spent by the State upon this work, but also co-ordination of effort and attention to administrative details. Our present plan is to leave work of this kind almost entirely dependent on local support; but the matter is not a local one, for a young engineer trained in one part of the country does not necessarily remain there. He may be employed in another district, or in some distant part of the Empire: he ought to be regarded as a national asset, and his training should be aided mainly from the *national* exchequer.

Moreover, the practice of leaving these matters to be determined locally leads to a squandering of such relatively small sums as are at present applicable for the purposes of higher technical education; for each local institution tries to go to the very highest point in as many branches of technical training as is possible, and presses its claims for a share of the available funds. The result is, a large number of technical institutions not nearly so efficient as similar German or American institutions are. Both in Germany and America we find large central institutions for this kind of education; the students in them are gathered together from a wide area, and are so numerous that it is possible to provide buildings and equipment on a scale greatly superior to anything in this country. Moreover, the authorities of these institutions are able to employ a staff of professors who can specialise to an extent which is unknown here. In few of our technical institutions is there more than one professor of, *e.g.*, electrical engineering; in the German and American ones there are numerous professors dealing with this vast subject; one specialising on central-station work, another on electric traction, another on dynamo-construction, another on telegraphy, and so forth.

Our Present Extravagance

Elementary Technical Education ought to be given in every town in the country, but higher Technical Education should be restricted to a limited number of important centres to which the best students from the smaller towns should be sent by means of scholarships. There is, however, little hope that this will be done so long as the matter is left largely in the hands of local bodies. The Government ought to be bold enough, and far-seeing enough, to step in and put a stop to the stupid and wasteful competition which exists to some extent at present, and is likely to increase, and to provide the necessary funds to make our great central institutions really worthy of our country.

But if this be done, the Government should take careful note of the fact that the successful technical institutions of Germany and America are, as a rule, free from ordinary academic control. The greatest German technical high school exists at Berlin side by side with the great University of that city, but as an absolutely independent institution. Similarly the great American technical high school, the Massachusetts Institute of Technology at Boston, exists side by side with the University of Boston, but in complete independence. For the main objects of a University are to disseminate knowledge and to extend its bounds without any regard to commercial considerations; the main objects of a Technical College are to disseminate knowledge of a useful character, and to extend its bounds in directions likely to be of service to trade and commerce. To subordinate the interests of Technical Colleges to the exigencies of a University is, therefore, a mistake, though

Freedom from Academic Control

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there is no reason why the colleges should not be incorporated in Universities as autonomous Faculties of Technology.

Another way in which the Government might help higher education generally in this country, would be by substituting for the ridiculously large number of competing examinations, under the burden of which Secondary Education in this country groans, a single State examination such as is provided in Germany, which could form the leaving examination for Secondary Schools and the entrance examination to the Universities, the Technical Colleges, the various professions, and the Civil Service. A certificate granted after an examination of this kind would be so valuable that each year more and more boys and girls would be allowed to continue at school until they had obtained it; and the disappearance of the miscellaneous collection of examinations under which we now suffer would be a very great educational advantage.

A better Examination System

So far, little has been said of the numerous evening classes in which technical instruction is given in this country. The reason is, that though much good may be done by the instruction of artisans and others in evening classes, the amount of knowledge which can be obtained in them is, as a rule, so small in comparison with that obtainable in day classes, that it cannot be regarded as likely to help us seriously in our efforts to put our captains of industry in a position to compete with the highly-trained products of American and German Technical Colleges. Indeed, a very large fraction of the work done in the evening classes is of an exceedingly elementary character; nevertheless, they are of value, because the best of the evening students pursue their studies for a considerable time, and so get an amount of knowledge worth having; and, in regard to the rest, even the small amount of knowledge they obtain is often of service to them. It may be hoped, however, that as secondary education improves, the need for a very large part of the elementary instruction now given in evening classes will disappear, though technological evening classes for artisans will probably always be needed.

Some years ago articles "made in Germany" were regarded as generally inferior to the products of this country; Germany was engaged to a very large extent in producing goods requiring for the most part unskilled and, therefore, cheap labour. The Germans made up their minds to alter this, and to secure for themselves a larger share of those industries which require the employment of highly-skilled and well-paid men. The extent to which they have succeeded may be gauged by the fact that they have secured by far the larger part of the trade in organic chemicals; that their ships are now the swiftest which cross the Atlantic; that their electrical machinery is competing with success with similar machinery produced in this country and in America; and that, while our exports of articles requiring skilled labour are almost at a standstill, those of Germany are rising by leaps and bounds. Thus the German exports of manufactured goods have increased in value no less than sixty-four per cent. in the last ten years; the corresponding increase for this country is only eight per cent. At the present rates of increase the total value of the German exports will soon exceed ours. If we consider our great engineering industries, we find that in 1880 we consumed nearly three times as much pig iron as Germany: she now uses for her manufactures over a million tons a year more than we do; our increase in twenty years is twenty-four per cent., while hers is 246 per cent. Or, if we take the manufacture of steel, we find that in 1880 we made twice as much as Germany; she now makes three million tons a year more than we do.

"Made in Germany"

Engineering Industries

This may, or may not, be partly due to our fiscal arrangements; but certainly few Germans would deny that a very large share of their success is due to higher technical education, on which Germany is spending so much care and money. The extent to which the Germans are gratified by this alteration in the industrial relations of their country and ours, may be gathered from the glee with which they painted in huge letters on the first German-American Liner which entered Southampton, after breaking all British records for speed, the words "Made in Germany." What was once the label of a third-rate article had in this, as in many similar instances, become a description of the best of its kind.

It is almost unnecessary to allude to the extent to which our markets are occupied by the products of American work directed by well-trained industrial leaders; we are all only too familiar with American tools, American tramcars, and American machinery, etc.; perhaps the most glaring instance of this is the "Twopenny Tube" in the centre of

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our metropolis itself, about which it may truly be said that there is scarcely anything which is British save the earth in which it is embedded.

In conclusion, it may be well to show by actual figures the extent to which a single German State contributes to education, and for this purpose we will not select one of the largest, but will take the kingdom of Würtemburg, with a population of about two million inhabitants, being less than one-third of the population of Greater London alone. This little kingdom has an annual revenue of £4,500,000, and expends no less than £386,200, or more than 8 per cent., on education.

If a country like Würtemburg can do this, what ought we not to expect from a great nation like the British—a nation whose very existence is bound up with the success of the trade and commerce on which by far the larger part of its population depends? May we not hope that, before it is too late, the present or some future Government may take steps to put higher education in this country on such a sound foundation that there may be no holes in our industrial and commercial armour, and that we may feel sure that in all that concerns education, our rising generation shall have advantages fully equal to those enjoyed by their German and American cousins?

The following figures* give the details of this expenditure :—

Description of School.	Amount of State Aid for 1901. £
State University at Tübingen	55,000
Technical High School	20,000
Agricultural High School	10,000
Veterinary High School	5,500
Building and Engineering Trades' School	10,800
Art Trades' School	5,000
Art School and Art Collections	7,200
Spinning and Weaving School	3,200
Vine Cultivation School	1,500
Gymnasia, Lyceums and Latin Schools	35,000
"Real" Schools (Modern Schools)	15,000
Industrial Improvement Schools	15,000
Masters' Training Institutes	19,000
Schoolmistresses' Training Institutes	5,000
People's Schools (Elementary Schools)	13,000
Additions to Salaries of Masters at Gymnasia, Lyceums, Latin Schools, Modern Schools and Elementary Schools	166,000
	£386,200

* These figures are taken from Dr. Rose's recent report on "Technical Instruction in Germany: Building and Engineering Trades' Schools."—Diplomatic and Consular Reports, No. 600, Miscellaneous Series.

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RAPID-CUTTING STEEL.

By PROFESSOR J. T. NICOLSON, D.Sc., M. Inst. C.E.

Two varieties of tool steel have for long been known, and distinguished from each other by the methods employed in hardening them. These are, ordinary water-hardened or carbon steel, and self- or air-hardening steel. The latter was discovered by R. Mushet, who found that by the addition of manganese and tungsten to tool-steel it maintained its cutting edge at much higher temperatures of the tool point, and that it was consequently possible to cut at much higher speeds than had previously been obtained with water-hardened steel.

The American Experiments

About three years ago an extensive series of experiments were undertaken by Messrs. Taylor and White, at the Bethlehem Steel Company's Works, Pa., U.S.A., upon this question. Their object was to clear up certain obscurities in regard to the hardening of steels, and to find out which brand was most suitable for heavy cutting at high speeds. These experiments appear to have been carried out in a thoroughly scientific manner, and consisted essentially in a long series of tests made upon tools of various chemical compositions, heated to different temperatures. Two hundred tons of forgings were cut up in carrying out the work.

The discovery, which was the direct result of these experiments, and which has had such a profound influence on the manufacture of tool steel and upon the design of machine tools, may, perhaps, best be explained by reference to the annexed table of figures, deduced from a curve published in the *Journal of the Franklin Institute* (Sept. 1901).

The first line gives the temperatures to which steel of the air-hardening variety is heated in the process of hardening, whilst the second line shows the resulting efficiency of the tool steel as expressed by its cutting speed.

It will be at once observed that the cutting power falls off very much if the steel is heated above 1550° Fahrenheit, and in the old days steel users were invariably warned by the manufacturers that the tool was not to be heated above a cherry red, otherwise it would be burnt and ruined. But by passing on beyond this "breaking-down point," as they called it, Messrs. Taylor and White found that, with certain compositions of steel, its efficiency as regards cutting began again to increase, and indeed reached a point far above anything that had before been attained. Even when heated up to 2000° Fahrenheit at which temperature it softens and crumbles when touched with a rod, the steel, when properly treated in cooling, will cut two or three times as fast as the old Mushet steel could.

Temperature (Fahr.)	1450°	1500°	1550°	1600°	1650°
Cutting speed (f.p.m.)	30	40	43	35	14
Temperature (Fahr.)	1700°	1750°	1800°	1850°	1900°
Cutting speed (f.p.m.)	16	75	93	108	120

As a result, the Bethlehem Steel Company were able to astonish visitors by their feats of high-temperature or high-speed cutting at the Paris Exhibition, but as they only performed upon very soft material, much doubt was felt as to the general usefulness of the results of their discovery.

The German Experiments

Many practical tests were immediately set on foot in workshops all over the world, but the opinions formed as the result of such sporadic trials were so conflicting that the Berlin Section of the "Verein Deutscher Ingenieure" decided to take the matter up, and in the spring of 1901 they set to work to ascertain the value and applicability of the new steel to general work. The valuable results of the extensive series of experiments which they made were published in the *Zeitschrift des Vereins* for 27th September, 1901. For the present article a diagram, Plate I., has been prepared in which a number of these results are reproduced for the benefit of non-German readers. This plate is described below.

The Committee of the Verein formed for

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the purpose of conducting these trials was assisted by the managers of some of the larger engineering establishments, and trials were first undertaken in these.

Although seven of the largest workshops in Berlin were available for the experiments, it was found that steels could not be tested therein to the limit of their power on account of: (1) shortage of material under normal working conditions; (2) lack of sufficient power; or (3) insufficient speed upon the lathes.

Thereupon the Niles Machine Tool Company placed a large lathe, and the German General Electric Company a motor, at the disposal of the Committee. With this combination a large number of trials was carried out in the Niles Works.

The object of the trials was to determine, keeping in view the durability or life of the tools:—

(1) What maximum surface could be machined in unit of time with a given cut of $\frac{3}{16}$ inch, the traverse and speed being left open.

(2) What weight of cuttings could be removed per unit of time with the greatest possible depth of cut, the traverse and speed being again left open.

The materials operated upon were grey cast iron, cast steel, and forged or rolled Siemens-Martin steel of various ultimate tenacities. The duration of each trial was intended to be two hours.

The tool steels were supplied by three firms:—

(*a*) *Bergische Stahl-Industrie*, of Remschied, who supplied their ordinary air-hardened steel, marked "L."

(*b*) *Gebrüder Böhler & Co.*, Vienna and Berlin, who supplied two varieties, "Titan-Boreas" and "Rapid."

(*c*) *Poldi-Hütte*, of Vienna and Berlin, who supplied their steels called "Diamant-000" and "Schnelldreher."

About 250 trials were made; and a selection of the best of the results obtained is given in the following tables, in English units.

These results have, as already mentioned, also been plotted, and smooth curves drawn through them in Plate I. The three full-line curves indicate the speeds of cutting which were attained, for the various sectional areas of cut, upon three kinds of Siemens-Martin steel, of which the ultimate strengths were 26 to 32 tons, 40¼ tons, and 49 tons per square inch respectively; their chemical composition being given in a subsequent Table (VII.), where they are distinguished by the letters A, B, and C, in order named. The three curves marked S.F.P.S., M.F.P.S., and H.F.P.S., are those deduced from the Manchester experiments (described below), and are inserted here for comparison. It is probable that the softest English steel operated upon (Whitworth fluid-pressed) was much tougher than the softest Siemens-Martin steel employed at Berlin; it certainly was much more difficult to cut. The hardest German steel, on the other hand, appears to have been more difficult to cut than the hard fluid-pressed steel used at Manchester. The spots *not* marked with the letters A, B, or C are of unknown tenacity.

The thick-line-dotted curve gives the speeds and areas for the German experiments on cast iron, whose chemical analysis is recorded

BERLIN EXPERIMENTS.

TABLE I.—SIEMENS-MARTIN STEEL.

Brand of steel used.	Trial.	Duration.	Cut.	Traverse.	Area of cut.	Cutting speed.	Weight removed per min.	Surface machined per min.	Skin or not.	Quality of Steel.
	No.	Minutes.	Inches.	Inches.	Sq. ins.	Feet per min.	lbs.	Sq. ft.		
P. S. .	261	20	·091	·0670	·0061	194	3·33	0·950	No.	..
P. S. .	263	63†	·170	·0670	·0114	136	4·84	·678	No.	..
Bo. R. .	136	95	·181	·0906	·0164	126	5·92	·808	No.	.
Bo. R. .	432	22	·223	·1025	·02286	91	6·16	·636	No.	A*
Bo. R. .	433	30	·260	·1140	·02962	72	7·50	·733	No.	A
Bo. R. .	106	155	·232	·0394	·00913	69	2·33	·259	No.	..
Bo. R. .	434	60†	·260	·0945	·02455	65	3·22	·497	No.	A
Bo. R. .	430	113	·197	·1160	·02285	45·2	3·21	·399	No.	B
Bo. R. .	103	135	·343	·0630	·0216	41·3	2·82	·216	No.	..
P. D. .	219	140	·232	·1045	·0244	35·5	2·64	·313	No.	..
Bo. R. .	429	120†	·492	·0945	·0464	31·6	4·71	·237	No.	B
Bo. T. B.	412	120†	·473	·0513	·0243	17·4	1·43	·075	No.	C
Bo. R. .	413	250†	·256	·0513	·0131	35·5	1·1	·162	No.	C

* See Table of Chemical Analysis *infra*. † Signifies that the steel was capable of further cutting.

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BERLIN EXPERIMENTS—*continued.*

TABLE II.—Cast Iron.

Brand of steel used.	Trial.	Duration.	Cut.	Traverse.	Area of cut.	Cutting speed.	Weight removed per minute.	Surface machined per minute.	Skin or not.
	No.	Minutes.	Inches.	Inches.	Sq. ins.	Feet per min.	lbs.	Sq. ft.	
Bo. R. .	425	59†	·1456	·1850	·0269	72·9	7·39	1·107	No
P. D. .	515	61†	1870	·1002	·0316	50·3	5·21	·775	No
Bo. R. .	424	120†	·520	·1034	·0850	47·3	14·43	·71	No
Bo. R. .	409	120†	·579	·096	·0556	37·4	6·25	·291	No
Bg. St. I.	611	120†	·559	·093	·0352	37·4	4·61	·226	No
P. D. .	514	120†	·520	·1417	·0737	35·4	7·39	·3875	No
P. D. .	275	103†	·300	·1437	·0431	35·4	5·65	·484	No
Bg. St. I.	633	30	·516	·1013	·0832	33·5	10·45	·538	No
Bg. St. I.	326	148†	·306	·0807	·0343	33·5	4·31	·237	No
P. D. .	273	190	·4375	·1043	·0456	27·6	5·74	·306	Skin

TABLE III.—Cast Steel.

Brand of steel used.	Trial.	Duration.	Cut.	Traverse.	Area of cut.	Cutting speed.	Weight removed per minute.	Surface machined per minute.	Skin or not.
	No.	Minutes.	Inches.	Inches.	Sq. in.	Feet per min.	lbs.	Sq. ft.	
Bo. R. .	420	120†	·2265	·097	·01517	47·3	2 457	·28	No
Bo. R. .	419	120†	·2106	·097	·01450	33·5	1·45	·189	No
P. D. .	271	100†	·590	·0275	·01622	31 55	2·346	·097	Skin
Bg. St. I.	624	120†	·394	·0512	·02018	26·6	2·149	·1185	No
Bg. St. I.	328	133†	·2205	·086	·01896	21·7	2·777	·151	No
Bg. St. I.	623	120†	·610	·0512	·03122	19·71	2·149	·0862	No
Bg. St. I.	619	120	·630	·0512	·03225	18·72	2·071	·0754	Skin
Bo. R. .	416	120	·630	·0492	·03100	17·73	2·115	·0862	Skin

† Signifies that the steel was capable of further cutting.

Brands of tool steel:—Bg. St. I. = Bergische Stahl Industrie.
Bo. T. B. = Böhler Titan Boreas.
Bo. R. = Böhler Rapid.
P. D. = Poldi Diamant 000.
P. S. = Poldi Schnelldreher.

in Table (VII.). The thin-line-dotted curves, marked S C I, M C I, and H C I are the Manchester results for soft, medium, and hard cast iron; the region between the two first, in which the Berlin results fall, being hatched.

Some valuable information regarding cast steel, deduced from the German records, is indicated by the dot-and-dash line in Plate I. No information regarding this material was obtained by the Manchester Committee.

The Manchester Experiments

A number of British firms have recently specialised in making rapid cutting steels, and it was with the object of testing the capabilities and commercial value of these brands that the experiments instituted by the Manchester Association of Engineers were undertaken. The expense of these trials, which was not inconsiderable, was jointly borne by that association, by the Municipal School of Technology of Manchester, and by the firm of Messrs. Sir W. G. Armstrong, Whitworth and Co. The report upon them was presented at a meeting of the above association held on October 24th, 1903, and was published *in extenso*, in *Engineering* of October 30th and November 6th. This report, although confined strictly to an account of the mode of experimenting, of the results obtained, and of a few of the more obvious deductions from the latter, is a sufficiently lengthy production, containing, as it does, twenty-nine tables of figures and thirteen plates. It is an excellent example of the kind of work which the engineering colleges and the higher technical schools in this country ought to undertake, and must be prepared to perform, if they are to occupy the place of similar institutions abroad in the very important matter of practical research on current engineering questions. In carrying out the work here under discussion, the Municipal School of Technology showed

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itself in the sphere of usefulness for which its engineering department, in a special sense, was primarily equipped, not merely as an institution for teaching young men the elements of engineering science, but also as an establishment where industrial experiments can be carried out on a practical scale.

The planning, execution, and reporting of this extensive series of trials is also a good instance of the results which can be attained by the united efforts of the educational and the industrial authorities. In carrying them out there have been combined the sound and discriminating common sense of the practising engineer, represented by such men as Mr. Daniel Adamson, Mr. H. N. Bickerton, Mr. E. G. Constantine, and Mr. George Daniels, who were the working members of the committee; the liberality of the renowned firm who provided the sinews of war, in the shape of 12 or 15 tons of forgings and castings to be cut up; and, lastly, the trained staff and the facilities and instruments for experimenting which were available at the School of Technology.

The questions which the committee set themselves to answer in these trials may be shortly stated as follows:—(1) What maximum speeds can be obtained with the new steels when taking light or finishing cuts upon hard, medium, and soft steel, and upon hard, medium, and soft cast iron? (2) What maximum area of surface can be machined in a given time when taking a $\frac{3}{16}$-in. cut with the new steels upon the six given materials? (3) What is the greatest weight of cuttings which the new steels can remove in a given time from these three grades of steel and cast iron? (4) What forces are operative upon the tool in making these cuts, and according to what laws do these forces vary with the speed of cutting and the area and shape of the cut? (5) Can the new steels be forged and tempered by an ordinary smith, and yet be relied upon to give results as to cutting speed and durability similar to those obtained when they are delivered ready ground by the makers?

Variation of Cutting Speed with Area of Cut.

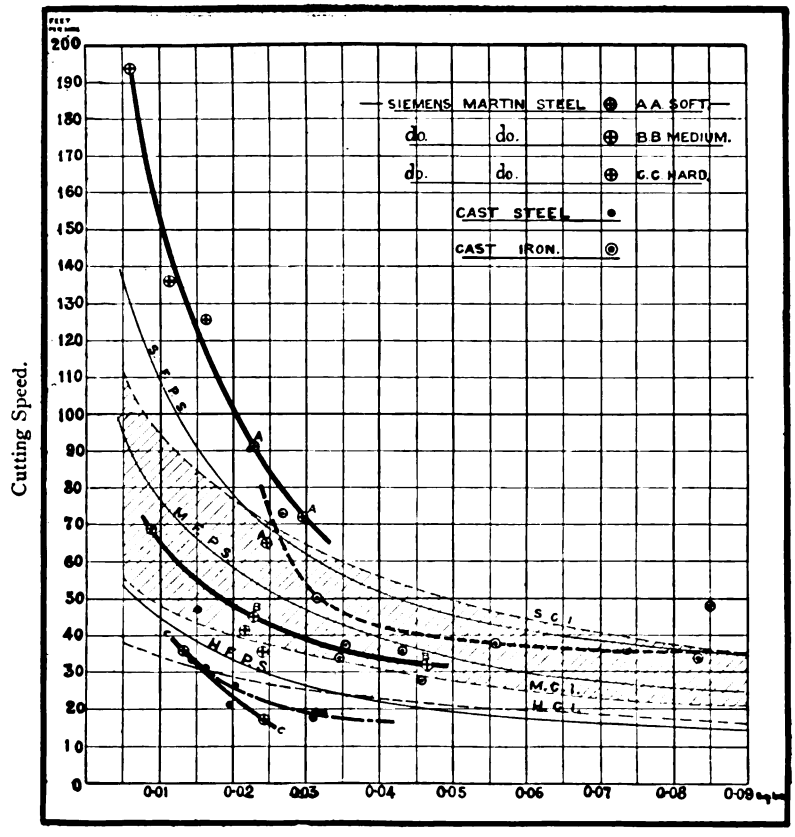

PLATE I.—AREA OF CUT—(CUT × TRAVERSE).

Comparison of Perlin and Manchester Experiments.

The answers to the first four of these questions are contained in Table IV., abstracted from those of the report.

This table is self-explanatory, and it need only be added that, as the cutting force was found to be closely proportional to the area of section of cut (*i.e.* product of actual cut and traverse), it is possible to give, as in the

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last column, the average cutting stress for each variety of steel or cast iron, irrespective of the size or shape of cut taken.

One of the most noteworthy facts discovered is, that the cutting force does not increase, but appears rather to diminish, with increasing speeds. This is contrary to the opinion generally held by turners and machine-tool experts, as instanced by the objections raised by workmen to an increase of the cutting speed on account of the anticipated springing of the work. This objection will no longer hold good, for, although higher speeds of taking a given cut will, of course,

MANCHESTER EXPERIMENTS.

TABLE IV.—Weights Removed, Areas Machined, and Cutting Stresses.

Intended cut and traverse.		Actual area of cut.	Maximum speed of non-fuling tools.	Weight removed.	Area machined.	Average cutting stress.
Inches.		Square inches.	Feet per minute.	lbs. per minute.	Sq. feet per min.	Tons per sq. inch.
Soft Steel (Whitworth Fluid-Pressed).						
1/16	1/16	·0032	149·2	1·72	·755	115
1/16	1/16	·0106	111·0	4·14	·575	
1/16	1/8	·0215	74·0	5·28	·756	
1/8	1/8	·0434	50·7	7·50	·511	
Medium Steel (Whitworth Fluid-Pressed).						
1/16	1/16	·0039	105·2	1·50	·547	108
1/16	1/16	·0114	80·0	3·17	·417	
1/16	1/8	·0227	51·4	3·88	·539	
1/8	1/8	·0425	38·6	5·60	·403	
Hard Steel (Whitworth Fluid-Pressed).						
1/16	1/16	·0040	52·5	0·73	·273	150
1/16	1/16	·0124	41·2	1·71	·214	
1/16	1/8	·0219	30·8	2·30	·320	
1/8	1/8	·0452	20·2	3·10	·210	
Soft Cast Iron.						
1/16	1/16	·0039	109·0	1·30	·567	51
1/16	1/16	·0124	99·5	3·60	·518	
1/16	1/8	·0214	66·2	4·38	·690	
1/8	1/8	·0459	55·5	7·46	·578	
Medium Cast Iron.						
1/16	1/16	·0033	59·7	0·69	·308	84
1/16	1/16	·0115	49·0	1·73	·254	
1/16	1/8	·0227	33·1	2·23	·335	
1/8	1/8	·0446	24·3	3·32	·249	
Hard Cast Iron.						
1/16	1/16	·00375	38·5	0·48	·200	82
1/16	1/16	·01173	31·9	1·18	·167	
1/16	1/8	·02112	24·7	1·62	·257	
1/8	1/8	·04590	22·0	3·2	·230	

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Variation of Cutting Force and Cutting Speed with area of Cut.

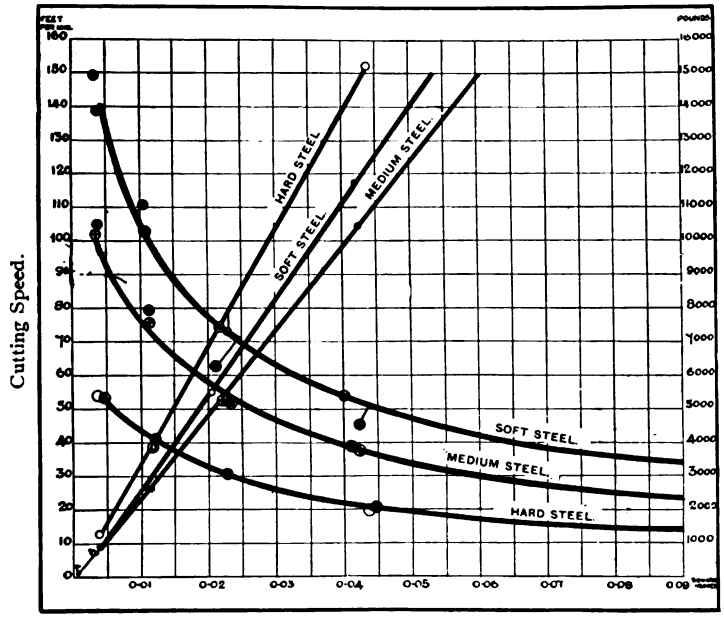

PLATE II.—AREA OF CUT—(CUT × TRAVERSE).

require a greater driving power almost in direct proportion to the increased speed, no greater, but rather a smaller, force will be brought upon the tool; so that the load acting upon belts and gearing, and the tendency of the lathe and work to spring will be rather diminished (except for gapped work) than otherwise.

On the other hand, it has been conclusively shown by these trials that heavy cuts at moderately high speeds will remove much more material than light cuts at the highest possible speeds the tool can stand. For the cutting speed does not increase as fast as the area of the cut diminishes, so that more material can be machined off in a given time with a heavy cut, than with a light cut at its corresponding faster speed.

Further, the total or gross horsepower required for cutting consists of the sum of that lost by friction of the intermediate gearing and of the lathe, as well as the effective work spent upon cutting. Now the frictional or lost power does not vary much, whether there is a heavy or a light cut on the machine; it therefore forms a much larger percentage of the whole at light cuts than at heavy cuts, and the latter are much more economical in power than the former.

The particular results of the Manchester experiments, which will probably prove to be most useful in practice, are those which indicate a law connecting the permissible speed of cutting with the product of depth of cut and width of traverse feed per revolution, or "area of cut."

In endeavouring to give a simple expression to this law it has been found that a curve

Variation of Cutting Force and Cutting Speed with area of Cut.

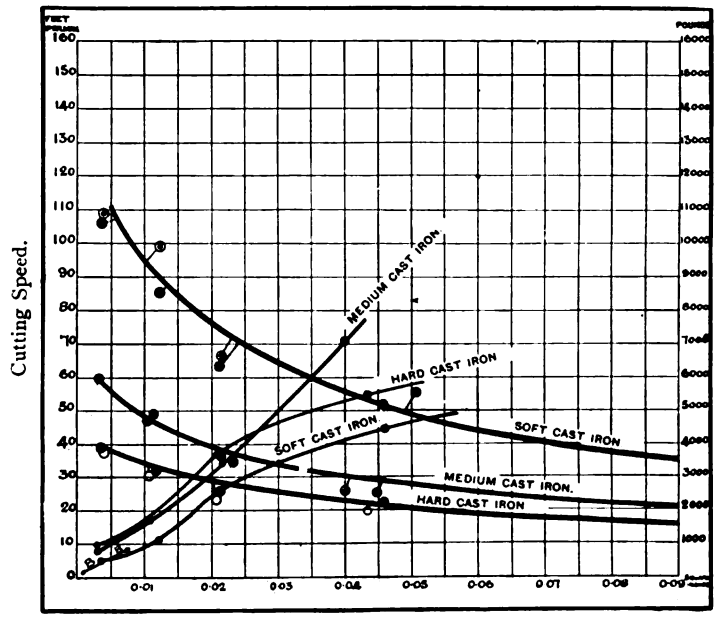

PLATE III.—AREA OF CUT—(CUT × TRAVERSE).

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closely approximating to a rectangular hyperbola, with asymptotes parallel to the axes of speed and area of cut, can be drawn through the co-ordinates of the results obtained in the trials for each material. Such curves, with the actual spots of the trials to which they approach, are plotted in Plate II. for steel, and Plate III. for cast iron; and in each case for the three degrees of hardness of the material operated upon. The ordinates are

On the same diagrams, II. and III., are also plotted the lines showing the relation between the forces upon the tool required for cutting, and the areas of cut taken on the trials. These relations are linear for all the varieties of steel, but are of complex form for cast iron. The average values of the cutting force divided by area of cut are tabulated, for each material, on page 92 in the last column of the Table there given.

Diagram of Weights Removed and Cutting Speed on area of Cut.

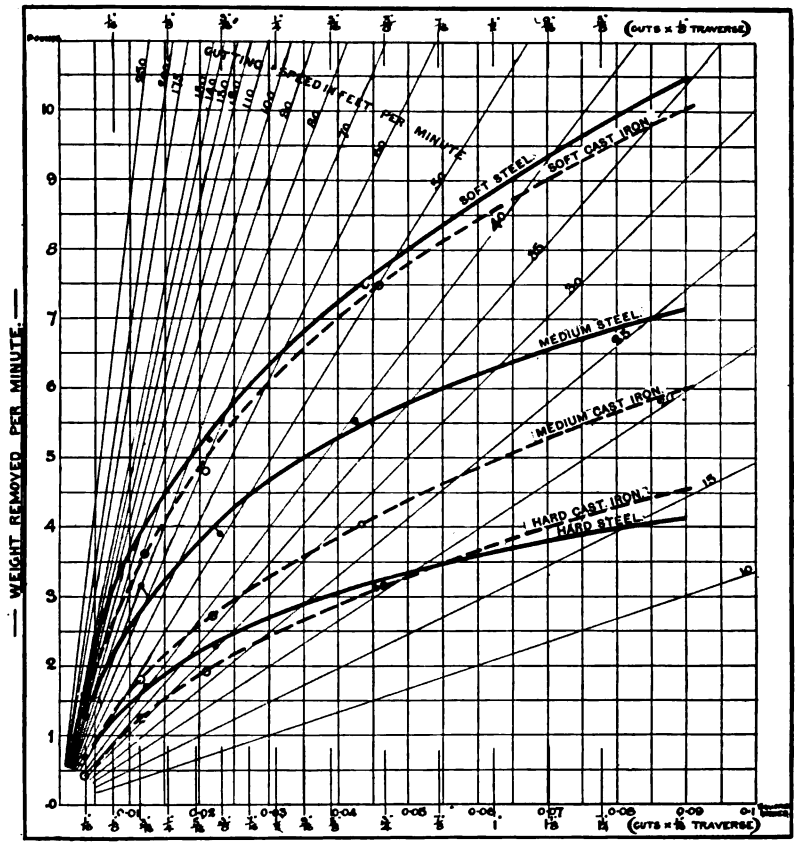

PLATE IV.—AREA OF CUT—(CUT × TRAVERSE).

speeds in feet per minute, the abscissae areas of cut in square inches. The following form of expression gives the relations for all six cases :—

$$v = \frac{K}{a + L} + M$$

Where a is the area of cut in square inches, v is the allowable cutting speed in feet per minute, whilst K, L and M are constants, of which numerical values, for the various materials, are given in Table V.

In Plate IV. are shown curves approximating to the weights removed per minute in the Manchester experiments. The full lines are for steel, the dotted for cast iron. The spots give the actual results obtained, being the greatest weights removed by any non-failing tool, on each of the four series of trials made with the six samples operated upon. As ordinates we have lbs. removed per minute, as abscissæ area of cut (or depth of cut multiplied by width of traverse). Since

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CONSTANTS IN FORMULA FOR CUTTING SPEED.
TABLE V.

Constant.	Fluid-pressed Steel.			Cast-iron Bars.		
	Soft.	Medium.	Hard.	Soft.	Medium.	Hard.
K . .	1·95	1·85	1·03	3·10	1·65	1 30
L . .	·011	·016	0·16	·025	·030	·035
M . .	15	6	4	8	7	5·5

$W = \mu a v$, where μ is the density of the material, a the area of cut, v the speed, and W the lbs. removed per unit of time, we have $\frac{W}{a} = \mu v = \tan\alpha$, say. This means that if a sloping line be drawn through the origin of coordinates of the diagram of weights and cuts, making with the axis of areas an angle α, whose tangent is μv, this sloping line will join points giving the weights which will be removed for each cut at the given speed v (if this were a possible speed). Such sloping lines will in fact be (contour) lines of constant speed, and are a useful addition to the diagram of weights removed. Thus, *e.g.*, if we wish to know at what speed 5 lbs. per minute can be removed, we can tell at a glance, by running across the diagram upon the 5 lbs. line, that the speed would have to be 200 ft. per minute for a $\frac{1}{8}$" by $\frac{1}{16}$" cut (0·00391 area), 96 ft. per minute for a $\frac{1}{8}$" by $\frac{1}{8}$" cut (0·0156 area), and 33 ft. per minute for a $\frac{3}{8}$" by $\frac{1}{8}$" cut (0·047 area). The first speed is impossible on materials operated on, the second is problematic, and the third could only be taken upon the milder varieties of steel. Or, conversely, we can tell the weights which will be removed if we run at a given speed on a given material; also the depth of cut and width of traverse we may safely employ.

The following Tables (VI. and VII.) give the particulars of chemical composition and ultimate strength of the materials operated upon in both the Berlin and Manchester experiments.

A few words may, in conclusion, be added regarding the explanations offered by chemists of the extraordinary efficiency and durability, under high temperatures, of the new steels. A series of systematic experiments, carried out in the works of the Poldihütte Company, have led to the following enunciation of the matter (see *Stahl und Eisen*, 15th April, 1902).

The carbon in the air-hardening steels forms carbides, not only with the iron, but also with the other metals, such as chromium, tungsten, etc., which they contain. The iron carbides are as a rule in the unhardened state, whilst at certain higher temperatures the iron has the property of giving off the carbon,

CHEMICAL COMPOSITION.
TABLE VI.—Cast Iron.

		Soft. *26 9 tons to the sq. in.	Medium. 44 tons to the sq. in.	Hard. 43·5 tons to the sq. in.
	Berlin.	Manchester.		
Carbon (total) . .	3·91	..	..	..
Combined . . .	0·45	0·459	0·585	1·150
Graphite . . .	3·46	2·603	2·720	1·875
Silicon . . .	2·05	3·010	1·703	1·789
Manganese . . .	1·00	1·180	0·588	0·348
Sulphur . . .	0·10	0·031	0·061	0·1614
Phosphorus . .	0·10	0·773	0·526	0·732

* Crushing strengths.

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CHEMICAL COMPOSITION.

TABLE VII.—FORGED STEEL.

	Siemens-Martin.			Whitworth Fluid-pressed.		
	A †26 to 32 tons to the sq. in.	B 40¼ tons to the sq. in.	C 49 tons to the sq. in.	Soft. †26·3 tons to the sq. in.	Medium. 28·9 tons to the sq. in.	Hard. 46·7 tons to the sq. in.
	Berlin.			Manchester.		
Carbon .	0·30	0·54	0·63	0·198	0·275	0·514
Silicon .	0·05	0·21	0·20	0·055	0·086	0·111
Manganese	0·58	0·93	1·22	0·605	0·650	0·792
Sulphur .	0·05	0·025	0·05	0·026	0·037	0·033
Phosphorus	0·07	0·05	0·05	0·035	0·043	0·037

† Ultimate tensile strengths.

which then shows a greater affinity for chromium and tungsten, forming carbides with them. These metallic carbides are fixed by rapid cooling; and, as they possess the property of hardness to an extraordinary degree, they are able to impart this to the steel into whose composition they have entered. Also this hardness is retained when the steel is much heated, for the new carbides are not altered by temperature, except beyond certain limits. This constitutes the radical difference between self-hardening and pure carbon steels. With the latter the hardness, due to the well-known combination of the carbon and iron, is lost after a small amount of heating. With the former the steel may be very considerably heated without losing its hardness, *i.e.*, its cutting properties. The limits which may be reached without injury depend, not only on the total percentage content of carbon and metals, but also upon the proportion of the former to the latter.

The matter may perhaps be roughly generalised as follows: Combined carbon gives hardness, whether it be in the form of iron, chromium, tungsten, or other metallic carbide. Mechanically mixed carbon does not increase the natural hardness of iron. Thus white or hard cast irons contain 2½ per cent. of combined carbon and less than 1 per cent. of graphite, whilst soft or grey cast iron contains only 1 per cent. of combined carbon to 2½ per cent. of graphite.

In hard carbon steel the greater proportion of the carbon is present in combination with the iron, whilst in the soft variety the greater part seems to be in intimate mechanical mixture with the iron, for it is left undissolved on treating the steel with an acid.

In the case of either the cast iron or the carbon steel, rapid cooling promotes or maintains chemical combination, whilst slow cooling allows the carbon to crystallise out.

In steels in which chromium, tungsten, etc., are present, the carbon deserts the iron and clings to these other metals at high temperatures, such as 2,000° Fahrenheit, and when the steel is cooled at such comparatively slow rates as occur in an air-blast, these metallic carbides are not broken up, and the steel remains hard. These carbides also possess a very much greater hardness than the iron carbide, and are only decomposed at very much higher temperatures than those at which the latter breaks down.

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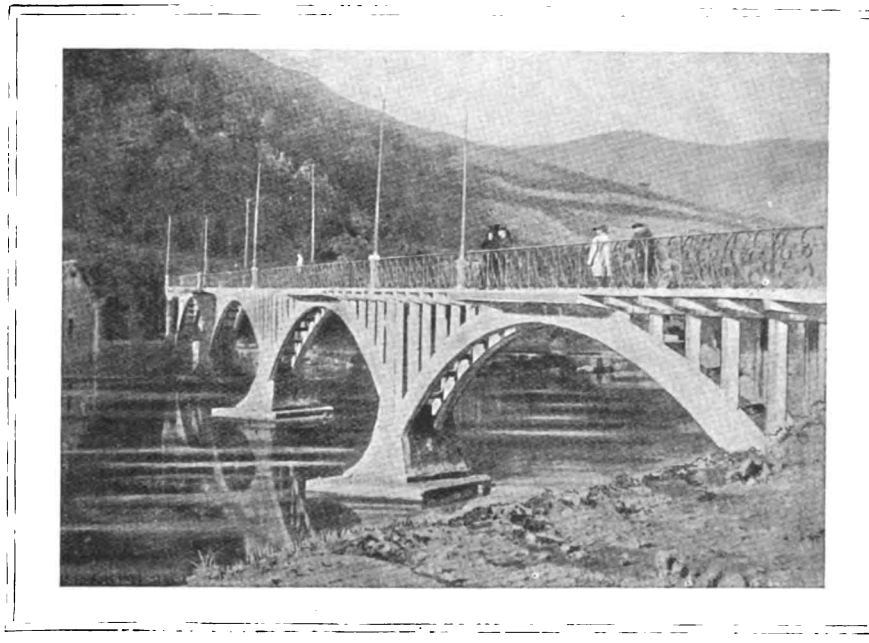
STRUCTURAL DESIGN.

By E. FIANDER ETCHELLS.



BRIDGE ACROSS THE RIVER NERVION AT BILBAO, SPAIN.

THIS bridge, entirely in Hennebique's ferro-concrete, erected for the passage of an electric tramway, comprises three arches, perpendicular to the axis of the river, and two skew arches at 45°. The span of each arch is 115 feet, with a span of ⅛th. Each arch is composed of two ferro-concrete arched beams, supporting pillars, on which the floor of the bridge has been constructed. The whole form a monolithic construction of great strength. The bridge was constructed in three months.

I AM asked to write a short article on the design of steel structures, and the trend of modern structural design. A short article must necessarily be sketchy and fragmentary, for to deal with the subject at all completely, a monopoly of the pages of this magazine would be required for the next twelve months. I might as well be asked to compress the whole art of structural design into a sixpenny telegram as to compress it into one short article. I can, however, give the pith in less than twelve words: (1) Learn from the artisan. (2) Use your common sense. (3) Study mathematics. Now let me be more definite. I say, learn from the artisan, because this appears to me to be the natural way, and it will prevent the student from designing structures and details which are impossible of execution or unnecessarily expensive. As an instance of this, I have seen steel stanchions with gusset-plates cut to the curve of a true ellipse, instead of leaving a straight edge. These unnecessarily expensive gussets were not for a theatre or restaurant, but were under some coal-bunkers. I say, use your common sense, as this will prevent students crowding two ¾ in. rivets into a 2½ in. bar, or showing rolled steel joists on the drawing which cannot be found in any maker's list. I have seen both these things done, not by students, but by alleged professional men. In fact, I was once informed that a rolled steel cantilever, unknown to any maker's list, but proposed to be used for a projecting street sign, "would be specially rolled." I say, study mathematics, because it will ultimately save you, or your employers, hundreds of pounds in economising material by the right proportioning of parts, and will enable you to cut your materials to finer limits than if you had only vague notions of the possible forces on each bar or member. In the old days, men ensured safety by putting in extra material, and being very lavish when in doubt. Now that competition is so keen, and contracts are so frequently let on the lowest tender, economy of design is very

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essential. Thousands of pounds are wasted annually through badly-proportioned structures. At this moment I have in view a football stand, to shelter a definite number of people, which was ordered on the express condition that it was not to cost above a stated amount. The makers complained afterwards that they had lost on the work. Now an analytical investigation of the strengths of the various parts showed that an equally strong structure could have been produced at seventy-five per cent. of the cost, and doubtless twenty-five per cent. profit would have been very acceptable. Another case in point is the following :—Suppose several firms are invited to tender for storage tanks of definite capacity. All other things being equal, that firm will get the order whose tanks have the largest capacity per square foot of plate area. This proportioning is a problem in the higher mathematics, and students should at least be familiar with the results, even though they may not follow every detail employed in the calculations.

In studying mathematics, however, I would suggest that engineering students take up some course of practical mathematics, for there are some branches of pure mathematics of very, very remote assistance in practical work, and other branches of vital importance. Statics, and graphic algebra or co-ordinate geometry, are very essential to the structural engineer. A training in very elementary algebra will be necessary, so that we may use the essential engineering formulæ with confidence and celerity, and so that we may verify the formula. Be sure that every formula you use is applicable to the case. I have known students use obsolete formulæ for iron beams when they are dealing with modern rolled steel joists. I have known persons use the orthodox formula for a rolled steel joist, when that joist was not loaded in the orthodox manner, with the result that their calculations were out by about 50 per cent.

Be sure that every formula you use is correctly printed. Remember that the compositors are not necessarily mathematicians, and also that mathematicians are not necessarily good penmen, and that mistakes do occur.

It is advisable to analyse every formula you can, and try and check it from first principles. This will give you a very good idea of the assumptions which are made, and will prove good and useful mathematical training. Remember that in nearly all our calculations we assume an ideal case, and the truth of our calculations will largely depend on how near the real case approaches the ideal one we have assumed. For instance, in measuring the length of a straight bar we assume perfect and absolute straightness, a condition unrealisable in ordinary practice.

It is absolutely necessary for students to study mathematics, so that they can make the calculations for any partially unprecedented case. A man may be on safe ground when he has formulæ for the problem in front of him, and a stress diagram for a similar case to fall back upon, but suppose he is asked to design an entirely new structure, say a new type of theatre girder; of what use are his inapplicable diagram and irrelevant formulæ? Again, mathematics becomes necessary, or you are likely to be deceived by the alluring advertisements of somebody's patent steel stanchions or somebody's indestructible featherweight trough decking. In the advertiser's hands the laws of nature and the axioms of mathematics become very pliable. Again, without a little elementary algebra the tabulated strengths of materials given in makers' lists will be very confusing. With a few outstanding exceptions, such lists are not to be relied upon. I append a table showing the comparison of the maximum safe loads from various section books for a rolled steel joist.

COMPARISON OF TABULATED SAFE LOADS FROM VARIOUS LISTS.

The section chosen for comparison is a 10" × 6" rolled steel joist, span 10 feet. All figures are for distributed stationary loads.

Section book.	Weight of joist per foot.	Maximum safe load in tons.	Maximum stress on extreme fibres.	Nature of end conditions.	Ultimate statical tensile strength of steel.
	lbs.		Tons per sq. in.		Tons per sq. in.
A.	39	18	7·5	?	28 to 32
B.	45	18·4	6·4	free	28 to 32
C.	42	19·7	7·0	,,	28 to 32
D.	42	21	7·5	,,	28 to 32
E.	45	23	8	,,	28 to 32
F.	42	25	10	,,	28 to 32
G.	42	25	?	?	?
H.	42	26	?	fixed	?
I.	42	26·2	?	,,	?
J.	42	28·6	?	free	28 to 32
K.	45	30	?	,,	28 to 32
L.	45	30·7	10	,,	28 to 32

It will be noticed that, according to the list, the maximum safe uniformly distributed load on a 10 in. × 6 in. rolled steel joist for a span of 10 ft. varies between eighteen and thirty-one tons, *i.e.*, a difference of 70 per cent. between the lowest and the highest. The variety in these results does not arise solely through the quality of steel used, but chiefly from the factor of safety employed, and the different assumptions as to the fixity

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or freedom of the ends. Unfortunately, some of the lists do not give these essential details, or they are given in small print and demand laborious searching after, yet thousands put their whole trust in these lists with a faith that is amazing in this sceptical age. At this juncture I would impress upon all students, architects, and draughtsmen, the necessity of giving the weight of a joist as well as its depth and width. For instance, 10 in. × 6 in. rolled steel joist leaves us in doubt whether a 39 lb. or 45 lb. joist is intended, and we are consequently ignorant of the strength of the joist intended. The same thing applies to steel angles and tees. It is not sufficient to say a 3 in. × 3 in. It is necessary to give the thickness as well. Is $\frac{1}{4}$ in. thick intended, or $\frac{3}{4}$ in.? This may seem a trifling matter, but I assure my readers that on architects' drawings this third dimension is frequently most noticeable by its absence. Such omission is as bad as ordering a pot of paint and not specifying the colour.

If you are to be successful as structural engineers it will be necessary to keep notes of all the standard details you can, and to gather trustworthy formulæ for the most frequently occurring problems. As an instance of standard practice, I give a copy of some fragmentary notes I have found useful in settling the details of bases of rolled steel stanchions for small sheds.

STOCK SIZES OF ROLLED STEEL STANCHION BASES FOR SMALL SHEDS.

Outside dimensions.	Base plate.	Size of angles.	Rivets.
Inches.	Inches.	Inches.	Inch.
6 × 3	12 × 8 × $\frac{3}{8}$	3 × 3 × $\frac{3}{8}$	$\frac{3}{4}$ diameter.
6 × 5	12 × 10 × $\frac{3}{8}$	3 × 3 × $\frac{3}{8}$	$\frac{3}{4}$,,
7 × 3$\frac{3}{4}$	12 × 10 × $\frac{3}{8}$	3 × 3 × $\frac{3}{8}$	$\frac{3}{4}$,,
8 × 4	12 × 10 × $\frac{3}{8}$	3 × 3 × $\frac{3}{8}$	$\frac{3}{4}$,,
8 × 5	15 × 12 × $\frac{3}{8}$	3$\frac{1}{2}$ × 3$\frac{1}{2}$ × $\frac{3}{8}$	$\frac{3}{4}$,,
10 × 4$\frac{1}{2}$	15 × 12 × $\frac{1}{2}$	4 × 4 × $\frac{1}{2}$	$\frac{7}{8}$,,
10 × 5	15 × 12 × $\frac{1}{2}$	4 × 4 × $\frac{1}{2}$	$\frac{7}{8}$,,

As an instance of frequently occurring formula, I give the usual formula for normal wind pressure against inclined surfaces, together with a note or two on its simplification.

$$P_n = P \sin a^{1\cdot 84 \cos a - 1} \text{ (Unwin)}$$

where P = pressure of wind per unit area on a surface at right angles to the direction of the wind.

a = angle of inclination of the direction of wind to a second surface.

P_n = normal pressure of wind per unit area on this second surface.

Unwin states "that the usual direction of the wind is probably horizontal, though it is quite possible that this direction may occasionally make a considerable angle with the horizontal, becoming, for example, normal to a roof of high pitch."

In practice, the pitch of roofs usually lies between 10 degrees for lean-to roofs and 60 degrees for Gothic roofs. Between these limits the normal wind pressure can be found from the following simpler formula, which gives practically the same result as Unwin's.

$$P_n = P \sin B \times \sin B$$
$$= P \sin^2 B$$
where $B = 1 \cdot 2\, a + 18°$.

For roofs higher than 60 degrees, the maximum horizontal wind pressure should be taken in preference to either formula.

In this matter of wind pressure, there are two other notes of outstanding importance. First, in an open lean-to shed with a flat roof, the wind may strike the face of the main building and beat downwards with great force, and destroy the flat roof; or, on the other hand, a wind pocket may be formed by the lean-to shed, and the wind, finding no escape, will lift the roof, so that our calculations of the horizontal component of the wind pressure on inclined surfaces become useless, as they do not apply to the case in hand. In dealing with flat roofs of this description, it becomes necessary to securely bolt them down, and to design them to safely stand a vertical downward pressure of at least 40 lbs. per square foot of ground plan, or an upward pressure from the under side of 20 to 30 lbs. per square foot, according to circumstances. In the case of downward pressures, this 40 lbs. includes the weight of the roof; and in the case of the 20 to 30 lbs. upward pressure the weight of the roof must be deducted to get the net upward pressure. These heavy pressures for flat roofs are justified by the experiments of Mr. Irminger, given in *The Gas World*, 6th May, 1899, and in greater detail by Mr. Nielsen in *Engineering*, on the 9th October, 1903. Mr. Irminger, however, takes up the subject from an entirely different standpoint. Secondly, it is also essential to remember that Hutton's experiments, on which the two formulæ given in this paper are based, were made on inclined surfaces with free escape of air on every side. Professor Kernot, of Melbourne University, has constructed a blowing machine, giving a fairly steady jet of air about 1 square foot in cross sectional area. To this jet he exposed numerous models of buildings, and measured the wind pressure

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on the various surfaces. He found the only cases in which the ordinary methods of calculations for wind pressure on roofs agree with practice are: 1st. A roof on columns with free air space underneath. 2nd. A roof lying on the ground without raised supports.

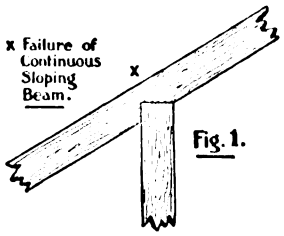

Fig. 1.

In the case of a roof supported on walls as far as the eaves, no pressure whatever was experienced on the roof.

In the case of a roof on walls, having parapets above the eaves, there was actually a negative pressure, producing a decided tendency to lift (*vide* Lineham's "Mechanical Engineering" and the "Transactions of the Australasian Association for the Advancement of Science," Vols. V. and VI.).

I give these notes here, as they are rather too recent to have found their way into the generality of text-books.

In dealing with corrugated roofs, it must also be borne in mind that there is greater necessity for longitudinal wind bracing, as the wind will catch the sides of the corries, and produce a racking tendency. If this is not taken up by wind bracing, it will be taken up by the sheets themselves, with the result that the hook bolts may work loose in the holes in the sheets. In designing open sheds for wharves, etc., it is often desirable to use angles and tees even for the tension members, so that the roof will not fail even if the wind does get under it. If the shed is open on all sides, this is not so necessary as when it is closed on three sides with the fourth side open to the river or dock.

Let us, however, turn from particular designs to designs in general. There is one general aspect of structural engineering which would considerably assist our progress in all its branches.

It is to realise, and to realise fully, that no matter what structure we take up, it is to be considered as a particular instance of the doctrine of evolution. Any given structure is as much the product of evolution as any particular animal is the product of evolution in the organic world. There is a continuous chain of progression between the first stepping stones thrown across a rivulet and the great spans of the Forth Bridge. There is an unbroken connection between the lake dwellings of pre-historic Europe and the ferro-concrete residence of M. Hennebique, of Paris. Some of the recent stages in this evolution are very clearly seen. Take first the wooden roof with the parts tied together by thongs or cord, as seen to-day in the South Sea Islands. At a considerably later stage of development, we see wooden roofs with iron nails or bolts through the joints. Next we meet with composite roofs, with wooden struts and rafters, and iron tie-rods. After this we find all-iron roofs. Later the iron is replaced by steel roofs and corrugated iron sheeting.

Take next the case of floors with wooden floor joists and wooden flooring. This differentiation of function betokens considerable previous development. These wooden floor joists are later replaced by steel joists with concrete filled in between. At a later stage we meet with steel floor joists completely imbedded in concrete. This leads to the use of floors of concrete with diminutive joists running through. The most recent stage of this tendency is seen in the distribution of steel into numerous round bars of small diameter running through the tension side of the concrete, as exemplified in the case of the Hennebique constructions.

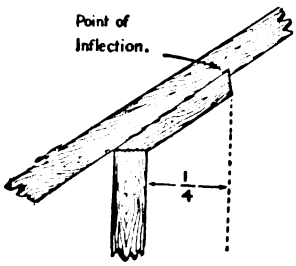

Fig. 2.

The advantage of this comprehensive view of the subject is, that the student feels greater confidence in himself, when he realises that any particular type of structure is only one link in a great chain, instead of each type of structure being "a special creation" with a special set of rules, formulæ, and diagrams. In this great slow march of evolution, experience and theory each take their due part. Neither theory nor practice is predominant, but they are each complementary. Improvements in design are forced upon our attention largely by accidents and disasters which have occurred in the past, and theorising as to how they may be prevented in the future. That is, our structural successes are amendments on the structural failures of the past,

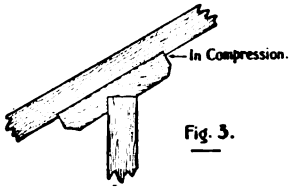

Fig. 3.

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and we to-day are making mistakes which those who come after us will have to rectify. During November, 1903, some railway arches collapsed between Cheltenham and Honeybourne, on the Great Western Railway, during process of construction. An enquiry will be held as to the cause. These arches will be compared with other arches which have stood the test of time, the materials will be examined, suggestions as to the cause of failure will be put forward, and various theories will be tried and tested; till, by a process of elimination, we find the true cause or causes of failure. The knowledge gained will thus be of use to us in designing and erecting the new arches or foundations. It is by such a process as this, though not necessarily so speedy, that each modern building or structure has evolved, and if we would desire a comprehensive view of the wide domain of structural engineering, we must look at every structure from the standpoint of evolution. I would however clearly impress upon you that I do not for a moment assert that every structure is an advance on its structural predecessor. Evolution includes such phases as arrested development, atavism, atrophy, and successive cycles of evolution. I have seen modern structures which would throw discredit on a builder of a mud cabin. I have seen the central pier of three piers made weaker than the end ones, although it took the greatest load. The failure of a football stand recently was due largely to "bird-mouthing" the raking beams at one of the points of maximum bending moment. (See Fig. 1.) Alternative methods allow us to get the bearing surface without materially affecting the transverse strength of the beam, as shown in Figs. 2 and 3.

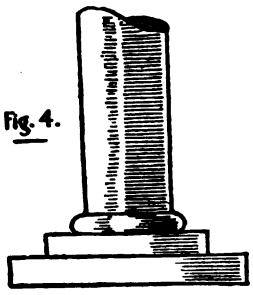

Fig. 4.

There is another important point in structural evolution to which attention should be drawn. It is the persistence of certain forms and details long after the use or necessity of that form has passed away. This persistence of early forms is most clearly seen in much of our modern ornaments, as these forms frequently served some real and useful purpose in the past. Let us take the case of a column. (See Figs. 4 and 5). Here the contour is rational when executed in wood, or blocks of stone, but when this form is used for a cast iron column it becomes meaningless, and even a source of weakness. A more suitable form for a cast iron column base is given in Fig. 6. Among other "vestiges of earlier forms" must be classed the meaningless spandrels or ornamental brackets under the rolled steel cantilevers of the iron and glass shelters outside hotels and theatres. In the days of wooden hoods or cast iron cantilevers, they served a useful purpose, but under a rolled steel joist they are almost invariably superfluous and very frequently a public nuisance.

It is also an essential principle of good design that every structure should be the "fittest" for the work it has to do. Herein lies the beauty of the bridge over the River Nervion, shown at the beginning of this article. Here will be found the horizontal beams forming the roadway, the vertical pillars in the spandrels, carrying the load from the flooring down to the arch itself; and the arch poised between pier and bank in such a curve that we seem almost to visualise the line of resistance sweeping through the arch's centre-line. We see also the sloping abutments, and the piers spread out to distribute the loads over the requisite foundation area. There is in every point such adaptability of form to function as must needs command approval. I believe it was John Strain, Member of the Council of the Institution of Civil Engineers, who first introduced concrete arches, but we have in this ferro-concrete arch across the Nervion what is doubtless the latest production of the structural engineering world. It is for the students of to-day to declare, in their maturity, whether this type of construction will hold its own in the commercial struggle for existence.

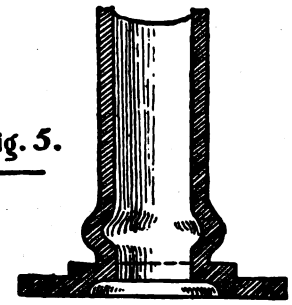

Fig. 5.

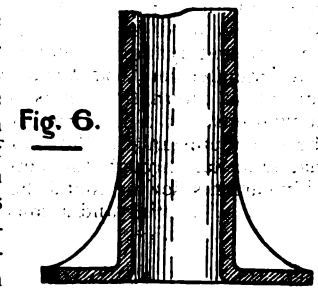

Fig. 6.

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ANSWERS TO QUERIES.

STUDENTS wishing for the solutions of problems, or assistance in their scientific or technical studies, are invited to consult the Technical Editor by letter. Queries should be accompanied by the name and address of the sender, together with a *nom de plume* for publication. Queries obtained from text-books or examination papers should be accompanied by particulars of the sources from which they are derived. Queries should reach us before the 10th of the month to be answered in the next month's issue.

ALEX.—In what circumstances would you select as an electro-magnet (*a*) one wound with many turns of very fine wire; (*b*) one wound with few turns of thick wire; (*c*) one with its core made up of a number of stampings of sheet iron?—*City and Guilds of London.*

An electro-magnet wound with many turns of fine wire would be selected when it is required to be connected as a shunt across any part of a circuit. The degree of magnetic saturation depends on the product of the number of turns and the current, *i.e.* on the ampère-turns, so that a very small current circulating many times round the magnet core will produce a high degree of saturation. If fine wire is used, the resistance of the winding will be very high, and only a very small current will be diverted from the main channel to which the winding forms a shunt. The degree of magnetisation will depend on the P.D. maintained between the ends of the winding. This method of winding is used for the magnet system of a shunt-wound dynamo or motor.

A winding consisting of a few turns of thick wire would be used when the main current in a circuit is required to act as the magnetising current. The degree of saturation obtained will depend on the current, since, as before, it depends on the number of ampère-turns, and, with a given winding, the number of turns is constant. The low resistance of the winding insures that, even although the current is large, there will be but little energy dissipated in the form of heat. This method of winding is used for the magnet system of a series-wound dynamo or motor.

A laminated core is used when the magnetising current is alternating, or is subject to rapid fluctuations. If a solid iron core were used in these circumstances, the variations of the magnetic flux through the core would produce eddy currents flowing round the core, and these would entail heating and a considerable loss of energy. The stampings are generally insulated from each other by layers of paper or varnish, so that eddy currents are eliminated. A laminated core is used for alternating current transformers.

TRACTION.—An electrically driven railway train, weighing 100 tons, travels 10 miles along a line which rises 600 feet in the distance, the tractive force on the level being 12 lbs. per ton. Find the number of kilowatt hours required to do the work, efficiency of motor and gearing being taken at 82 per cent.—*City and Guilds, Electric Lighting and Power, Ordinary Grade,* 1903.

In raising 100 tons through 600 feet, the work done will be equal to

$$100 \times 2240 \times 600 = 144{,}400{,}000 \text{ ft.-lbs.}$$

To keep the train in motion on the level, a constant pull is required amounting to

$$12 \times 100 = 1200 \text{ lbs.}$$

This pull acts through a distance of 10 miles, or 52,800 ft.; hence the work done in keeping the train in motion through the distance specified amounts to

$$1200 \times 52{,}800 = 63{,}360{,}000 \text{ ft.-lbs.}$$

$\therefore$ Total work performed

$$= 144{,}400{,}000 + 63{,}360{,}000$$
$$= 207{,}760{,}000 \text{ ft.-lbs.}$$

Now 550 ft.-lbs. per second = 746 watts

$\therefore$ 550 ft.-lbs. = 746 watt-secs.

$$= \frac{746}{3600} \text{ watt-hours.}$$

$$\therefore \text{ 1 ft.-lb.} = \frac{746}{550 \times 3600} \text{ watt-hours.}$$

Thus, if the efficiency had been equal to 100 per cent., the watt-hours required would have been equal to

$$\frac{207{,}760{,}000 \times 746}{550 \times 3600} = 78{,}300 \text{ watt-hours nearly.}$$

This is equivalent to 78·3 kilowatt-hours.

Since the efficiency of the motor and gearing is equal to 82, for each 82 kilowatt-hours required according to the above calculation 100 kilowatt-hours must be supplied. Thus the kilowatt-hours supplied must amount to

$$\frac{78{\cdot}3 \times 100}{82} = 95{\cdot}5 \text{ kilowatt-hours.}$$

CALORIC.—The temperature of a pond is 8° C. when a freezing wind sets in. Describe what happens as the water parts with its heat, and, assuming that it parts with it at a uniform rate, compare the time taken to the beginning of freezing with the time taken to freeze the top half-inch of water, the total depth being 20 inches.—*London University Matriculation, January* 1896.

The water loses heat from its surface, and so long as the surface layer is at a temperature above 4° C., the cold water sinks, and is replaced by warmer water from below. Thus the temperature of all the water in the pond will fall uniformly till it reaches 4° C. Subsequently the cold water at the surface of the pond remains there, and almost immediately after the pond reaches 4° C. a thin layer of ice will form on its surface. As time progresses, this layer of ice

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extends further down into the pond, the unfrozen water beneath it remaining at the constant temperature of 4° C.

The heat given up by each gram of water in cooling through 1° C. is equal to 1 heat unit. Thus the time which elapses before the whole pond falls in temperature to 4° C. (at which point freezing commences), is proportional to

$$20 \times (8-4) = 80.$$

Now 80 heat units are given up by each gram of water that freezes: therefore the time required for the top half-inch of water to fall in temperature from 4° to 0° C., and then to freeze, is proportional to

$$\tfrac{1}{2} \times 4 + \tfrac{1}{2} \times 80 = 42;$$

∴ time taken to beginning of freezing: time taken, from commencement, to point where half an inch of ice is formed, = 80 : (80 + 42)
= 80 : 122.

LUX.—If the refractive indices for red and blue light respectively be 1·525 and 1·542 in a crown glass, and 1·628 and 1·660 in a flint glass, calculate the mean focal length of a flint glass lens which will correct the chromatic aberration of a convex crown glass lens of 50 cms. mean focal length. What will be the focal length of the combination when the two lenses are placed close together?—*London University Inter. Sci. Hon.*, 1898.

For the crown glass lens, let

f = the focal length,
μ_r = the refractive index for red rays,
μ_b = the refractive index for blue rays,
μ = the mean refractive index.

For the flint glass lens, let

f' = the focal length,
μ'_r = the refractive index for red rays,
μ'_b = the refractive index for blue rays,
μ' = the mean refractive index.

Then, for the combination to be achromatic,

$$\frac{\mu_b - \mu_r}{\mu - 1} \cdot \frac{1}{f} + \frac{\mu'_b - \mu'_r}{\mu' - 1} \cdot \frac{1}{f'} = 0. \quad (1)$$

$$\mu_b = 1{\cdot}542, \quad \mu_r = 1{\cdot}525.$$
$$\mu_b - \mu_r = 0{\cdot}017.$$
$$\mu = \frac{\mu_b + \mu_r}{2} = 1{\cdot}538.$$
$$f = -50.$$
$$\mu'_b = 1{\cdot}660, \quad \mu'_r = 1{\cdot}628.$$
$$\mu'_b - \mu'_r = 0{\cdot}032.$$
$$\mu' = \frac{\mu'_b + \mu'_r}{2} = 1{\cdot}644.$$

Thus, from (1),

$$-\frac{0{\cdot}017}{0{\cdot}538} \cdot \frac{1}{50} + \frac{0{\cdot}032}{0{\cdot}644} \cdot \frac{1}{f'} = 0;$$
$$\therefore f' = \frac{32}{644} \cdot \frac{538}{17} \cdot 50 = 78{\cdot}9 \text{ cms.}$$

Thus the flint glass lens must be divergent, and possess a focal length of 78·9 cms.

If F is the focal length of the combination, then

$$\frac{1}{F} = \frac{1}{f} + \frac{1}{f'} = -\frac{1}{50} + \frac{1}{78{\cdot}9}$$
$$= -\frac{28{\cdot}9}{3945};$$
$$\therefore F = -\frac{3945}{28{\cdot}9} = -136{\cdot}5 \text{ cms.}$$

EGO.—What is meant by the tensile strength of a liquid? How can it be measured?

Let an ordinary barometer tube be scrupulously cleaned, filled with pure dry mercury, and inverted with its open end below the surface of pure mercury in a containing vessel. Now let the barometer tube be depressed until the mercury contained in it just reaches to the upper (closed) end of the tube. At this point the length of the column of mercury enclosed in the tube is just equal to the barometric height.

If the barometer tube is now cautiously raised, it will be found that the mercury does not break away from the top of the tube, but apparently coheres to it, with the result that a column of mercury considerably longer than the barometric height can be supported. In this operation the column of mercury originally in the tube has dragged some of the mercury from the containing vessel up into the tube and supported it there; thus the mercury column possesses tensile strength, and is able to support a weight, somewhat after the manner in which a weight may be supported by a wire.

The tensile strength of the mercury is the greatest stress per unit area which can be supported without rupture. Thus, if the mercury column becomes ruptured when it is h cms. longer than the height of the mercury barometer, the tensile strength is equal to—

$$h \times 13{\cdot}65 \times 981 \text{ dynes per sq. cm.}$$

GALVO.—The positive terminal of a Bunsen cell is connected, by a wire of negligible resistance, to the positive terminal of a Daniell cell, and the negative terminals of the two cells are then connected by a wire of negligible resistance. Calculate the difference of potential between the terminals of the Daniell cell, having given:—

Bunsen cell E.M.F. = 1·8 volts,
internal resistance = 0·02 ohm.
Daniell cell E.M.F. = 1·1 volts,
internal resistance = 0·5 ohm.

Since the E.M.F. of the Bunsen cell exceeds that of the Daniell cell, a current will flow from the + terminal of the Bunsen cell through the Daniell cell in a direction from the + to the − terminal. In passing through the Daniell cell there will be a fall of potential due to two causes. (1) Heat will be produced in the interior of the cell, and consequently energy is lost by the current; the drop of potential due to this cause is equal to Cr, where C is the current, and r the internal resistance of the cell. (2) Chemical energy will be stored up in the Daniell cell owing to the circumstance that the current deposits zinc on the negative plate. This storage of energy represents an energy loss to the electric circuit,

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and therefore produces a fall of potential ; the value of this fall is equal to the E.M.F. of the Daniell cell.

$\therefore$ P.D. between terminals of Daniell cell

$$= 1{\cdot}1 + Cr.$$

To find C, note that the resultant E.M.F. all round the circuit is equal to $1{\cdot}8 - 1{\cdot}1 = 0{\cdot}7$ volt. The total resistance in the circuit $= 0{\cdot}02 + 0{\cdot}05 = 0{\cdot}07$ ohm.

$$\therefore C = \frac{0{\cdot}7}{0{\cdot}07} = 10 \text{ ampères.}$$

Then, since the internal resistance, r, of the Daniell cell is equal to 0·05 ohms, we have

P.D. between terminals of Daniell cell
$= 1{\cdot}1 + 10 \times 0{\cdot}05 = 1{\cdot}6$ volts.

MAGNET.—Calculate the size, resistance and weight of copper wire such that, if wound on a cylindrical iron core 6 inches long, 3½ inches diameter, and having a P.D. of 50 volts between its terminals, 4,400 ampere-turns will be produced. The diameter of the completed coil is to be 7¾ inches. A cubic foot of copper weighs 550 lbs.— *Electric Lighting and Power Transmission, City and Guilds, Ordinary Grade.*

Since the innermost layer of wire has a diameter of 3½ inches, while the outermost layer has a diameter of 7¾ inches, the mean diameter of all the turns will be 5·625 inches.

Let there be n turns, the mean resistance of a turn being R ohms. Then the resistance of the completed coil will be n R ohms, and a P.D. equal to V volts maintained across its terminals will give a current of

$$\frac{V}{n R} \text{ ampères.}$$

The number of ampère-turns will be equal to

$$\frac{V}{n R} \times n = \frac{V}{R}.$$

Then, from the question,

$$\frac{50}{R} = 4{,}400$$

$$\therefore R = \frac{50}{4{,}400} = 0{\cdot}01136 \text{ ohms.}$$

R is the resistance of a turn of wire wound into a circle of 5·625 inches diameter.

The resistivity of copper, *i.e.*, the resistance of a copper cylinder 1 inch long, and of 1 square inch sectional area, is equal to 0·66 microhm at 60° F. If we assume that the working temperature of the coil is equal to 110° F., then the resistivity of copper at that temperature is equal to 0·72 microhms. (The resistivity increases by 0·21 per cent. per degree Fahrenheit.) Then, if r is the radius of the section of the wire, we shall have

$$R = 0{\cdot}01136 = \frac{0{\cdot}72 \times 10^{-6} \times 5{\cdot}625}{\pi r^2}$$

$$r^2 = \frac{0{\cdot}72 \times 5{\cdot}625}{3{\cdot}14 \times 0{\cdot}01136} \times 10^{-6} = 1{\cdot}13 \times 10^{-4}.$$

$$\therefore r = 1{\cdot}06 \times 10^{-2} = 0{\cdot}01065 \text{ inch.}$$

Now, r is the radius of the bare wire ; therefore the diameter of the bare wire is equal to 0·0213 inch. Allowing 5 mils (a mil = 0·001 inch) for the thickness of the insulation on the wire, the diameter of the covered wire will be equal to

$$0{\cdot}0213 + (2 \times 0{\cdot}005) = 0{\cdot}0223 \text{ inch.}$$

Assuming this wire to be wound evenly on the core, there will be

$$\frac{6}{0{\cdot}0223} = 269 \text{ turns per layer.}$$

Allowing for unavoidable unevenness in winding, we may take it that each layer will contain 260 turns. The thickness of the winding amounts to

$$\frac{(7\frac{3}{4} - 3\frac{1}{2})}{2} = 2{\cdot}12 \text{ ins.}$$

If the winding is executed so that the wires in one layer lie exactly over the wires in the layer beneath it, there will be

$$\frac{2{\cdot}12}{0{\cdot}0223} = 95 \text{ layers.}$$

As the winding may be a little closer than that assumed above, the wires in one layer lying in the depressions between the wires in the layer beneath, we may assume that there will be 100 layers.

Then n = total number of turns = 100×260 = 26,000. Total resistance of winding = $26{,}000 \times 0{\cdot}01136 = 295$ ohms. The volume of copper in a single (mean) turn is equal to

$\pi r^2 \times$ mean length of turn

$$= 3{\cdot}14 \times 1{\cdot}13 \times 10^{-4} \times 5{\cdot}625$$

$$= 1{\cdot}99 \times 10^{-3} \text{ c. inch} = \frac{1{\cdot}99 \times 10^{-3}}{1728} \text{ c. ft.}$$

Then the weight of copper in the whole winding will be equal to

$$\frac{26{,}000 \times 1{\cdot}99 \times 10^{-3}}{1728} \times 550$$

$= 16{\cdot}47$ lbs., or 16½ lbs. in round numbers.

Thus the diameter of the wire should be 0·0213 inch (bare) or 0·0223 inch covered. The resistance of the winding will be 295 ohms, and the weight of copper will be nearly 16½ lbs.

CALCULUS.—Find the value of the indefinite integral

$$\int \frac{x^{\frac{1}{2}}}{1+x}\, dx.$$

—*Elementary Treatise on the Calculus*, Gibson. No. 26, p. 297.

Let $x^{\frac{1}{2}} = z$.

Then $x = z^2$, and $dx = 2z\,dz$.

$$\int \frac{x^{\frac{1}{2}} dx}{1+x} = 2\int \frac{z^2 dz}{1+z^2} = 2\int \frac{(z^2+1-1)dz}{1+z^2}$$

$$= 2\int dz - 2\int \frac{dz}{1+z^2}$$

$$= 2z - 2\tan^{-1} z$$

$$= 2x^{\frac{1}{2}} - 2\tan^{-1}(x^{\frac{1}{2}})$$

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OPEN QUERIES.

QUERIES such as the following, which can best be answered by those who have had special experience, will be left open to the readers of TECHNICS to answer. Prizes will be awarded to the best answer to the following query; for particulars see p. 102. No answer should exceed 1,500 words; the greatest brevity, consistent with thoroughness, is desirable.

I am thinking of equipping a small engineering workshop for general purposes, largely for repair work. I intend to fit it with a few lathes, one or two shaping and planing machines, a slotting machine, and such milling machines and capstan lathes as my purse will from time to time permit. Above all, I want the whole scheme to be thoroughly modern in driving power, and on this point I am variously advised. Many urge me to relinquish the steam engine in favour of petroleum, but the failures and troubles of oil engines deter me, and I think I could compromise by the use of gas, of which there is a supply. The steam engine would seem to be more trustworthy, however; but here again I am in trouble as to choice, for while some friends advise a high-speed engine and dynamo, with electric distributors; others (and these I confess myself inclined to follow, because of my doubt and insufficient knowledge) still advocate the older slow-speed engine with shafting and belting. Finding that it is difficult to obtain definite advice founded on trustworthy data, I appeal to the kindness of the readers of "Technics," and shall be greatly obliged if any of these can oblige me with information regarding the founding of such a shop as I have suggested, giving, if possible, a comparison of the various systems as regards first cost, upkeep in repairs, wages bill, and liability to failure in the hands of ordinary workmen. I may mention that there is no central electric station near, from which I could buy electricity.

"TECHNICS" COMPETITIONS.

A GOLD MEDAL and £200
To be awarded Annually to the "Technics" Prizeman.

£100 IN PRIZES OFFERED IN THIS ISSUE.

THIS, our first number, contains particulars of fifteen competitions.

These will be continued in various forms throughout the year, and will probably amount to about 150 in all.

Our object is to discover the most brilliant students at the Technical Institutions throughout the British Empire; and by means of these competitions, to select one man who comes out pre-eminently above the rest. The student who shows the most care, thought, accuracy and brilliancy in these competitions will earn the title of the "Technics" Prizeman, and will receive a Gold Medal and £200 in cash.

In order to afford ample scope for all classes of students, care will be taken that the competitions shall have a wide range.

We have been fortunate enough to secure the advice and co-operation in this magazine of some of the most eminent men connected with technical study.

The award of this important prize will require considerable thought and knowledge on the part of the arbitrators. We shall, therefore, ask the kind assistance of the eminent men referred to, whose names will be a guarantee that the adjudication will be fair and just.

£100 IN PRIZES.

COMPETITIONS FOR STUDENTS AND OTHERS.

General Rules.

Competitors are requested to note the following rules:—

All writing must be on foolscap paper. Only one side to be written upon, and a reasonable margin left.

Competitors for the prizes offered for various designs should see that their drawings are sent either rolled or flat. They should not be creased. They must also be executed in black ink.

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All drawings, and each page of MS., must bear name and address of sender.

The Editors reserve the right to publish, without further payment, contributions that gain prizes. Should any article or drawing that has not gained a prize appear in the magazine, payment will be made.

Should the best answer in any competition be deemed of insufficient merit, the Editors reserve the right to withhold the prize.

All competitions should be addressed to the Competition Department, "Technics," 3 to 7, Southampton Street, Strand, W.C., and must reach these offices not later than February 10th. Results will be published as soon as possible.

In each case the work will be submitted to experts competent to declare which is the best practical suggestion, design, or article.

GENERAL COMPETITIONS.

1. The best description of "My Institute." The article dealing with this must not exceed 1,000 words. (Restricted to students.) First prize, £5; second prize, £3.

2. How this magazine can best help students. Length of article not to exceed 1,000 words. (Restricted to students.) First prize, £5; second prize, £3.

3. How this magazine can best advance Technical Education. Article not to exceed 1,500 words. Prize £10.

4. The best design for a pair of wrought iron entrance gates suitable for a park. Prize £5.

5. The best design for the car of a motor vehicle to carry four or six persons. Competitors should note that the several parts of the design must be proportioned to bear the strains entailed. Prize £10.

6. The best forecast of the practical development of wireless telegraphy. Length not to exceed 1,500 words. Prize £10.

7. For the best practical article dealing with the "Application of Electric Power to Railways." Length of article not to exceed 1,500 words. Prize £10.

8. The best design for a Headpiece for this Magazine, suitable for an article on Machinery. Prize £3.

9. The best design for a Tailpiece for this Magazine, suitable for an article on Photography. Prize £3.

10. The best answer to the Open Query on p. 101. Prize £5.

HOMEWORK PRIZES.

In May next valuable prizes will be awarded to the students forwarding the best homework books to the Editors of Technics. Full particulars will be published later.

SPECIAL COMPETITIONS.

Questions Bearing on Articles in this Number.

Five sets of questions, on articles in this number of Technics, will be found below. A separate prize of £5 will be given for the best answers to each set of questions. If two or more sets of questions are attempted by a competitor, the answers to each set must be made up in a separate packet, but all such packets must be posted under one cover.

Answers must be received by the Editors not later than February 10th.

The student furnishing the best single answer will receive a prize of £3.

These competitions are restricted to students.

I.

Dynamo Design.

1. An understanding of the subject of commutation is essential to the choice of the number of segments, and this also affects the choice of the commutator diameter. But so far as relates to thermal considerations, peripheral speed and other matters, the present article gives sufficient data. Proceeding from these data, what diameter and length of segment would you employ for a 10-pole, 500 kilowatt, 250 volt, 200 r.p.m. machine?

What size and quality of brushes would you use?

What would be the total commutator loss expressed in percentage of the rated output?

Give corresponding information for an 8-pole, 500 kilowatt, 1,000 volt, 200 r.p.m. machine.

2. Make similar calculations for commutators of 400 r.p.m. 500 k.w. machines for 250 volts and 1,000 volts respectively, the former having 8 and the latter 6 poles. From these results, and those obtained in answering Question 1, compile a table showing the influence of speed

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and voltage upon the component and total commutator losses, and state the general conclusions to which you have been led by these investigations.

3. A little thought will show that a two-circuit single winding for a 4-pole machine with 4 conductors per slot, and one turn per commutator segment, is inconsistent with the conditions of the fundamental formula—

$$C = n y \pm 2.$$

In practice, however, the difficulty may be overcome in several ways. How would you proceed in such a case? Discuss the subject, using winding diagrams to illustrate your plans. Some of the practicable methods have probably never been described. It is also probable that still other practical solutions may be devised.

4. An important matter, not discussed in this article, is that of equaliser connections for armature windings. These are nowadays often used in large continuous-current generators. They are described on page 109 of Dr. Thompson's "Design of Dynamos," and in other text-books on dynamos. What is the object of such equaliser connections? To which types of windings may they be most satisfactorily applied? What conditions must then be fulfilled as to number of segments and number of poles? Does the use of equalisers obviate wasteful currents in the armature winding? Does such use reduce the commutator heating? If so, for what reason or reasons? Give good reasons why it is preferable *not* to employ equalising connections provided suitable precautions are taken. In what do these precautions consist?

II.

Dyes and Dyeing.

1. Name as many as possible of the dye-stuffs in use before 1856, and the best modern substitutes for each among the colours derived from coal-tar.

2. What points must be specially considered in selecting a dye-stuff for any particular variety of textile material?

3. A material is woven from a grey cotton warp and a white woollen weft, and the wool is then dyed red in the piece. The cloth is intended for export to Australia. What class of dye-stuff would you recommend for the wool and the cotton respectively, and why?

4. Name several methods used for dyeing black on cotton and state the properties of the dyed colour in each case.

III.

Radium.

1. Discuss the points of similarity and dissimilarity between Light Rays, X Rays, Kathode Rays, and the α and β rays emitted by radium.

2. Some radium is contained in a small lead dish, the mouth of which is closed by a piece of black paper. The dish is stood, mouth upwards, on a photographic plate in a dark room, the dish is then placed between the poles of an electro-magnet. Give a diagram showing the paths of the α, β, and γ rays emitted by the radium, when the electro-magnet is excited. What effect will be produced on the photographic plate? How will this effect be modified if the polarity of the electro-magnet is reversed during the experiment?

3. What is the evidence that the heating and luminous effects produced by radium are not due to an ordinary chemical reaction?

4. What is the evidence that the heating and luminous effects of radium are not due to the absorption of some unknown radiations?

IV.

Structural Design.

1. What assumptions are made in the ordinary theory of bending of beams?

2. Take Unwin's formula for wind pressure on inclined surfaces, and find the value of P_n when P = 40 lbs. per square foot, and sin a = sin $26\frac{1}{2}°$. Show your working, and compare your answer with the value of P_n as given by the author's formula for roofs up to 60° pitch. Give the percentage difference between the two results.

3. Take the tabulated safe loads on a 10" × 6" rolled steel joist and find the stress on the extreme fibres in the case of H and K.

4. Give details of the failure of any roofs which have been destroyed by wind, stating clearly the method of failure. If possible, select a case within your own experience, giving data and particulars as to position of surrounding buildings, etc., and enclose a sketch.

V.

Textile Design and Manufacture.

1. On what basis has Fig. 1a been constructed? What are the standard methods of colouring such designs? State reasons why these methods are applicable.

2. Contrast the advantages or otherwise of obtaining the effects in the style represented in Fig. 9, by the weft or warp respectively.

3. It is stated in the article that "in certain examples no mathematical system of design has been used." Differentiate further between patterns of this type and those constructed on well known bases.

4. What are the essential characteristics of textile colouring, whether acquired by blending fibres or by crossing yarns in weaving?

REVIEWS OF BOOKS.

Scientific and Technological works forwarded to the Editors for notice in these pages will be promptly reviewed by competent critics.

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TECHNICS

FOR FEBRUARY

WILL BE PUBLISHED ON 9th OF THE MONTH,

Monthly, Ninepence Net.

AND WILL CONTAIN, AMONGST OTHER ITEMS:—

THE ROYAL COLLEGE OF SCIENCE, LONDON.

The Physical Laboratories described by Sir ARTHUR RUCKER, M.A., D.Sc., LL.D., F.R.S., Principal of the University of London. The Chemical Laboratories described by Professor TILDEN, F.R.S. Illustrated from the Plans and Drawings by ASTON WEBB, R.A.

POSSIBLE ADVANCES IN ELECTRIC LIGHTING.

By JAMES SWINBURNE, M.I.E.E., M.I.C.E., Past-President of the Institute of Electrical Engineers.

THE PHOTOGRAPHIC NEGATIVE.

By EDGAR SENIOR. Fully illustrated.

THE TRAINING AND EDUCATION OF LOCOMOTIVE APPRENTICES.

By D. DRUMMOND, M.I.C.E., Head of the Locomotive Department on the L. & S. W. Railway.

THE MUNICIPAL TECHNICAL SCHOOL, MANCHESTER.

Fully described and illustrated.

AN EXPERIMENTAL STUDY OF MIRRORS AND LENSES.

By E. EDSER, A.R.C.Sc., F.Ph.S.

THE BATTERSEA POLYTECHNIC.

Illustrated.

THE HEATING AND VENTILATION OF AN EDUCATIONAL BUILDING.

By W. W. F. PULLEN, A.M.I.C.E., M.I.ME., Wh.Sc.

&c., &c., &c.

There will also be continued Articles on "Charlottenburg," Class Illustration, Dynamos, and Constructional Design.

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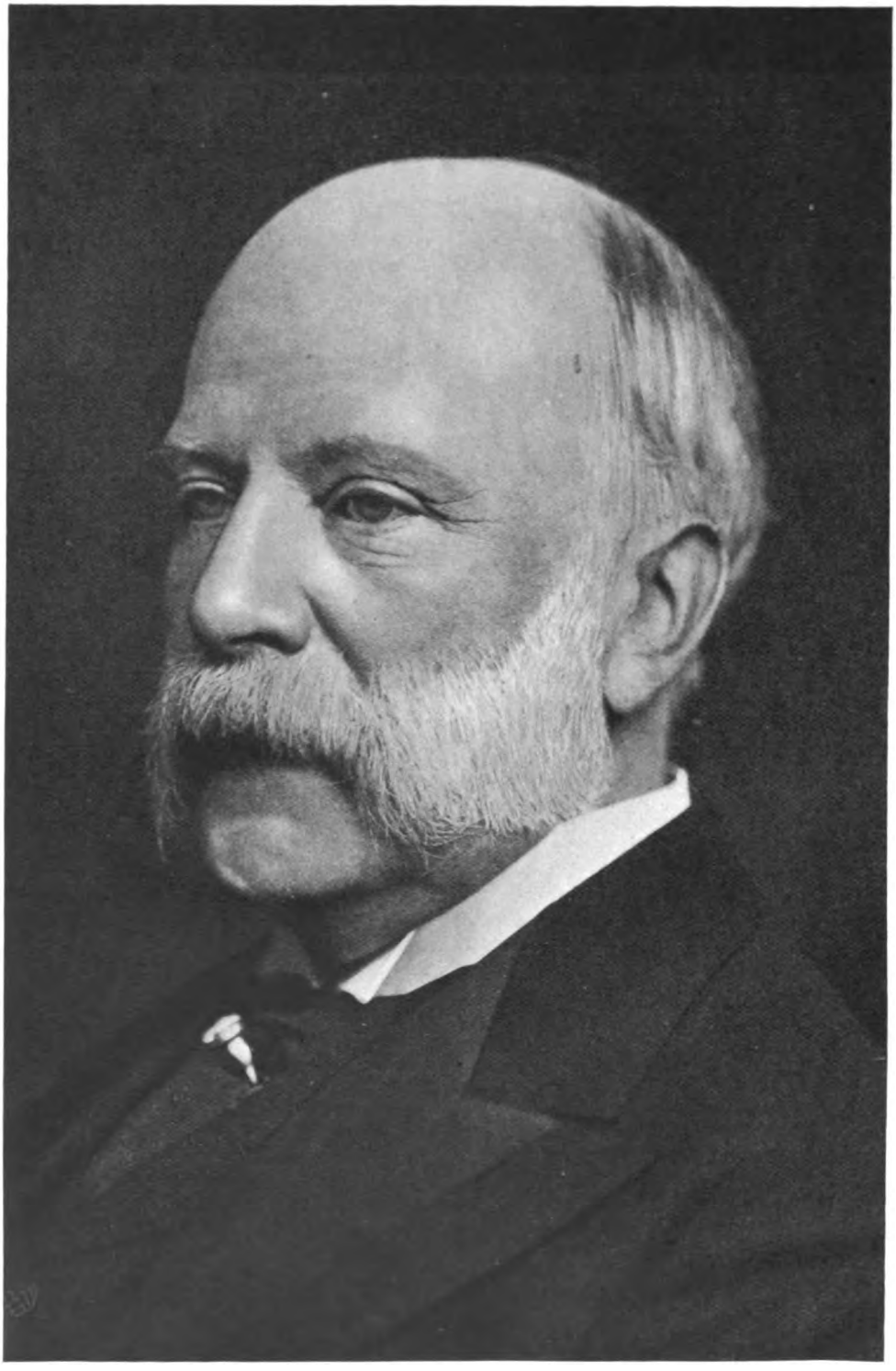

SIR ARTHUR W. RÜCKER, K.C.B., D.Sc., LL.D., F.R.S.

Principal of the University of London.

Photo by George Newnes, Ltd.

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TECHNICS

A MAGAZINE FOR TECHNICAL STUDENTS.

VOL. I. FEBRUARY, 1904. No. 2.

PROGRESS OF SCIENCE AND TECHNOLOGY.

IT has been found that the bromides of radium and barium are separated by fractionation more easily than the chlorides of the same elements, the time required for the preliminary treatment being reduced from three months to one month. This method was discovered by Giesel about two years ago, and has been in use ever since at the Chinin-Fabrik in Brunswick. Projects are afoot for obtaining radium from certain mines in Cornwall. It has also been announced by Strutt that the pipes through which the Bath waters have been pumped contain deposits which possess "appreciable quantities" of radium. It must be remembered, however, that extremely minute traces of radium can readily be detected, and thus we need scarcely be surprised to hear that the quantities in the pipe deposits are too small to repay extraction. Strutt's discovery is chiefly interesting as confirming Sir William Ramsay's conjecture, that the presence of helium in the Bath waters is due to the atomic disintegration of a dissolved radio-active substance.

Radium

Nature, for January 7, contains an interesting communication from Professor Rutherford. It has been suggested that the radio-activity of radium may possibly be influenced by the continuous bombardment to which the substance is subjected by its own radiations, so that a given quantity of radium, when diffused through a mass of pitchblende, may be less active than when concentrated in a small space. In order to test this point, Professor Rutherford measured the radio-activity of radium bromide in the solid state, and also when dissolved in more than a thousand times its own bulk of water. No appreciable difference in the rates of radiation could be detected in the two cases. This experiment shows that, over the range investigated, radium is unaffected, so far as its radio-activity is concerned, by its own intense radiation, a result in complete accordance with previous investigations. It further tends to show that the energy given out by radium is not due to the absorption of some unknown external radiation, similar in character to the radiations emitted.

Experiments on Radio-activity

The number of kinds of rays known to science is steadily mounting up, and one already begins to anticipate the day when each letter in the English, Greek, and one or two other alphabets, will be appropriated to some kind of radiation. First there were the X rays, and then the α, β, and γ rays of radium; before we have had time to become accustomed to these novelties, we hear of a new class of rays denoted by the letter N. Exactly what the N rays are, it would be difficult to say; indeed, until quite recently, no one has been able to observe them except their discoverer, M. Blondlot. This investigator has found, amongst other strange things, that on looking at the face of a clock in a dimly-lighted room, it appears to become brighter when a piece of wood is bent near the observer's eye. In explanation of this, it is stated that the strained wood emits rays which, though invisible themselves, yet have the property of rendering the eye more sensitive to light. Similar rays are emitted in a perplexing variety of circumstances. A Welsbach burner enclosed in a sheet-iron vessel emits them. A brick which has been exposed to sunlight emits them. Bodies in a state of molecular strain, such as pieces of tempered steel, also

N Rays

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emit them, and continue to do so, for incredible spaces of time: a knife found in a Gallo-Roman sepulchre was found to be still active at the present day. N rays traverse aluminium and paper without hindrance, but are absorbed by a thin layer of moist material. They can be reflected, refracted, and focussed. Their effect on the human eye appears to be only one of many eccentric properties. M. Blondlot states that when they fall on a slightly luminous flame, the flame becomes brighter, as can be tested by photographic methods. Zahn has attempted to verify this

FIG. 1.—PATTERN FOR WHICH GRATING WAS CAST.

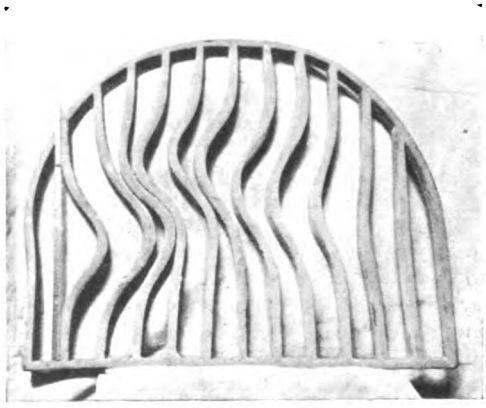

FIG. 2.—GRATING AFTER REPEATED HEATINGS.

latter property, but without success. On the other hand, Charpentier states that if a barium platino-cyanide screen, rendered faintly luminous by a fragment of radium enclosed in paper, is brought near to a muscle, the screen becomes perceptibly brighter when the muscle contracts. A similar effect is produced when the screen is placed near a nerve or nerve-centre, the effect being proportional to the degree of excitation of the nerve. Charpentier describes a process of mapping out the active muscles in the living subject, especially the heart, by the aid of N rays.

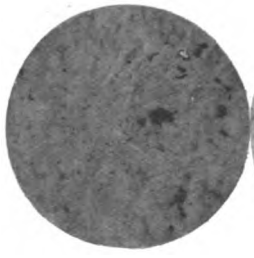

FIG. 3.—MICRO-STRUCTURE OF CAST IRON BEFORE HEATING.

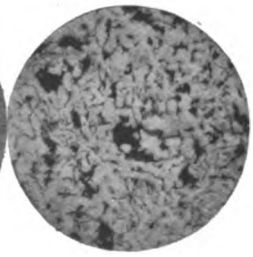

FIG. 4.—MICRO-STRUCTURE OF CAST IRON AFTER REPEATED HEATINGS.

The Molecular Mobility of Cast Iron

By the courtesy of the Editor of *Engineering* we are enabled to reproduce some photographs illustrating an important property of cast iron which is very little known. Fig. 1 represents the pattern of a cast iron protective grating for the floor of a core oven over a flue; Fig. 2 represents the grating after it had been in use for some time. The outside frame was protected from the direct heat of the fire, but the bars were subjected to repeated heatings and coolings. It will be seen that the bars have suffered a permanent elongation, which has caused them to become greatly distorted. This property of cast iron has been exhaustively studied by Mr. Alexander E. Outeridge, who is connected with the well-known firm of Sellers & Co., Philadelphia. It was found that a test bar of cast iron, originally 14·8 inches long, grew in length by one inch after it had been heated to redness and subsequently cooled twenty-three times. The initial density of the cast iron was 7·13 grams per cubic centimeter, while its final density was 6·86 grams per cubic centimeter. Further, it was found that when the bar had been permanently elongated by successive heatings and coolings, its coefficient of linear expansion was less than one-half that of the untreated bar. These results seem to show that furnace plates and stove-plates may be prevented from cracking by repeatedly heating and cooling the castings before they are put together. Prolonged heating without cooling does not produce the same result. A marked decrease in the tensile strength is produced by successive heating and cooling. Figs. 3 and 4, due to Mr. Job, chemist to the Reading Railway Company, are reproduced from

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photo-micrographs of polished specimens etched with dilute nitric acid. Fig. 3 shows the micro-structure of the unheated iron, while Fig. 4 shows the much coarser micro-structure produced by successive heatings and coolings. Mr. Outeridge has succeeded in utilizing the above properties in an interesting manner. A small pump was used, in connection with a type-casting and setting machine, for the purpose of forcing the molten type metal into the mould. The cast iron piston of this pump, originally ground to a diameter of 0·875 inch, was found to have worn rather rapidly, having been reduced in diameter to 0·869; the maximum clearance permissible was 0·008 inch. The piston was placed in an iron tube, the ends of which were luted up with fire-clay, and the whole was then heated and cooled five times, when it was found that the diameter of the piston had increased to 0·914 inch, a gain in diameter of 0·045 inch, or nearly eight times the increase needed. The metal appeared to the eye to be as fine grained as before, and was in good shape for re-grinding to size.

Molecular Mobility of Wrought Iron and Steel

Mr. Outeridge also found that permanent dimensional changes are produced in wrought iron and steel by repeated heatings and coolings. In this case, however, the change is less marked than in cast iron, and takes the form of a small shrinkage. This phenomenon has long been known, and may frequently be utilized with advantage when a part of a machine, though correct in its proportions, is slightly too large. Mr. Outeridge utilised this property in diminishing the size of a steel rocking bar 16 inches long, made for part of a type-casting machine, which was found to be a few thousandths of an inch too long. This bar had in it a number of lugs, spaced at regular intervals, the whole being cut out of a solid plain steel bar on a milling machine. It could not be shortened by milling off the ends, since this would have thrown the lugs out of their true relation to other parts of the machine; but after a few heatings in a furnace it was reduced to the required size.

Steam Turbines versus Piston Engines

Dr. Riedler, in an address recently delivered before the Berlin Shipbuilding Society (Schiffbautechnischen Gesellschaft) expressed the opinion that the days of the piston steam-engine are numbered. Mr. Robert H. Smith, writing in *The Engineer* of December 18, thus translates Dr. Riedler's utterances:—

"The normal piston steam-engine is no longer capable of material improvement either in respect of mechanical construction or of thermal action. A complete transformation of the steam-engine into the new form of steam-turbine is essential. . . . Turbines are much

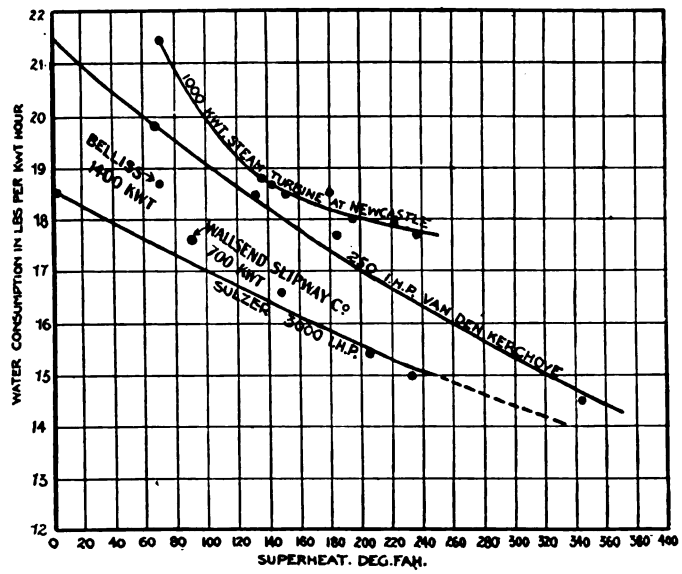
WATER CONSUMPTION IN LBS PER KWT HOUR
SUPERHEAT. DEG.FAH.
1000 KWT STEAM TURBINE AT NEWCASTLE
BELLIS 1400 KWT
WALLSEND SLIPWAY Co 700 KWT
SULZER 3600 I.H.P.
250 I.H.P. VAN DEN KERCHOVE

FIG. 5.—CURVES SHOWING STEAM CONSUMPTIONS OF DIFFERENT FORMS OF STEAM-ENGINES, PLOTTED ON A SUPERHEAT BASIS.

cheaper than piston engines, require less room, hardly any attendance, and use no more steam than the best piston engines. . . . The results of the last ten years' trials indicate that the turbine is the simplest and the best form of steam-engine. . . . The costs of erection, etc., are very small, and the bulk is from one-fifth to one-tenth that needed by a piston engine of equal power; they require no foundation, no fly-wheel, no added 'balance weights'; they have no dead points, and can be started equally well in any position of the shaft. They have no parts sensitively liable to leakage, and start as well cold as hot. . . . They have no internal parts requiring lubrication. . . . Internal combustion engines have beaten steam-engines because they give a doubly better utilization of the heat of combustion of the fuel; but only where waste gases are obtainable, as from blast furnaces and coke ovens, or where power gas is cheap. Therefore, steam-engines will be superseded by gas-engines at ironworks, many coal

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mines, and certain special workshops. This development has already in large degree begun in the ironworks of the Rhine and the Moselle valleys. The gas-engine would extend much beyond these limits in replacing steam-engines if it did not meet a new rival in the steam turbine."

In favour of Piston Engines

Many of Dr. Riedler's arguments cannot be questioned, but the superiority of steam turbines, so far as regards steam consumption, is not generally admitted. The curves (Fig. 5), showing the steam consumption of a number of piston engines, together with that of a Parsons steam turbine, were published in the *Electrical Engineer* of January 1, by a contributor signing himself "A Student.' The accompanying letter runs as follows:—

SIR,—As a small contribution to the controversy on the above subject, I am sending you a diagram I have prepared showing the performance of various engines, plotted on a superheat basis. These include:

(*a*) 1,000-k.w. steam-turbine at Newcastle, as given in Mr. Hunter's paper before the Institution of Mechanical Engineers (refer *Engineering*, August 1, 1902); 145-lb. steam, 26·5-in. vacuum, works-test nine-tenths full load; being presumably the tests quoted by Mr. Wilkinson in his paper, as the best figures agree with those given by him in comparison with the Bellis engine at Leeds.

(*b*) I have indicated by a spot the consumption of the Belliss 1,400-k.w. engine at Leeds, as per their letter in your recent issue; steam pressure, 180-lb.; vacuum, 25·6-in. Tests on site.

(*c*) Ditto, Wallsend Slipway engine at Newcastle (refer Mr. Minshall's paper, *Proc.*, Inst. C.E., vol. cli., p. 200); steam, 192-lb.; vacuum, 25·6-in. Test on site.

(*d*) Line showing performance of 3,000-h.p. Sulzer engine, as published in the *Engineer* of May 25, 1900; steam, 200-lb. condensing.

(*e*) Ditto, Van den Kerchove 250-h.p. engine (refer *American Electrician*, June, 1903); 130-lb. steam, 27·7-in. vacuum.

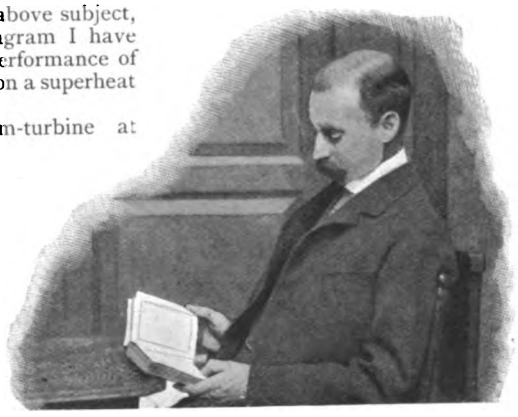
It will be noted that the turbine lies well away above any of the others, and that the gain due to superheating with the turbine is at a very low rate after about 140 deg. superheat, whereas the improvement with the reciprocating engines is well maintained. Is the turbine, after all, nearer its limit of economical performance than the reciprocating engine?

Yours, etc., A STUDENT.

Further possible improvement of the piston engine appears to be limited by the difficulty of obtaining a lubricant which is not carbonised by high temperature steam. The possibilities of improving the steam turbine are subject to no limitations on this account.

Recent tests on a Brown-Boveri-Parsons steam turbo-generator, installed at Frankfurt-a-M., of 4,000 h.p., gave the above results, extracted from the *Electrotechnische Zeitschrift*. These figures show that the steam turbine is a more formidable rival to the piston engine than the Newcastle experiments, quoted by "A Student," would lead us to expect

Temperature of Superheated Steam.	Output, k.w.	Steam consumption in lbs. per k.w.-hour.
298° C.	1,940	16·0
295° C.	2,520	15·7
312° C.	3,000	15·1



ASTON WEBB, R.A.
Photo by Fredk. G. Hollyer.

The Royal College of Science, London

For many years past, the laboratories of the Royal College of Science have proved too small to accommodate the number of students annually applying for admission. Efforts were made by the staff to overcome this difficulty: in one case the private room of one of the professors was temporarily turned into a class room; but when every available inch of space had been utilized, it was still found to be impossible to accommodate the ever-increasing number of applicants. At last the Government recognised these facts, and a sum of money was voted for the erection of new buildings. It was determined that laboratories and lecture-rooms for the physical and chemical departments should be erected opposite to the Imperial Institute, on a scale adequate to meet present and future requirements. These buildings are described and illustrated elsewhere in this issue. The style of architecture is dignified and impressive, befitting an

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important Government institution. But what renders these buildings most interesting, is the care which has been taken to adapt them to the needs of an educational institution. Sir Arthur Rücker is responsible for the arrangements of the physical laboratories and lecture-rooms; the arrangement of the chemical laboratories and lecture rooms was commenced by Professor Thorpe, and completed by Professor Tilden. No trouble has been spared to obtain results which combine the advantages of all existing institutions, both at home and abroad; and the architect, Mr. Aston Webb, has succeeded in planning a structure which possesses the highest artistic qualities, while it satisfies the exacting requirements of science. The new buildings of the Royal College of Science form a monument to our national enterprise of which everyone in the Empire may justly feel proud.

Workshop Science

Great diversity of opinion exists as to the training which is most suitable for engineering students. In some institutions great stress is laid on workshop practice, although it is difficult to see how a student can obtain the skill, which would fit him for work in the shops, during the time which can possibly be devoted to its acquirement in a course at a technical institute. In other cases, the aim has been to familiarize students with those properties of matter which an engineer has to deal with: this has from the first been the aim of Professor John Goodman's courses at the Yorkshire College, Leeds, which were arranged to make students acquainted with the principles that underlie the art of engineering, the art itself being more easily and naturally acquired in the works. Nevertheless, educational courses in engineering have seldom been arranged to impart a knowledge of those properties of matter which are utilized in ordinary workshop practice, although a knowledge of these properties is of the greatest importance, and should be the stock-in-trade of every skilled mechanic. Mr. W. Taylor has arranged a course on the *Science of the Workshop*, at the Leicester Municipal School, of which a syllabus will be found elsewhere in this issue. A glance at this syllabus will show how attractive and practically useful such a course may be made. Mr. Taylor is to be congratulated on a novel departure in the training of engineering students

Technical Education and the N.E. Coast Engineers

In May last, at a general meeting of the North East Coast Institution of Engineers and Shipbuilders, a committee was formed to report on the training of young men in engineering and shipbuilding works. The list of the members appointed includes the names of many of the leading engineers of the district, and the fact that these men have conscientiously devoted their time to the study of an educational problem is an omen of good augury for technical education in this country. The following is a list of the members who served on this committee:—Henry Clark, W. H. Dugdale, G. B. Hunter, Summers Hunter, F. T. Marshall, D. B. Morison, Robert Thompson, R. L. Weighton, and Henry Withy. Mr. John Tweedy acted as chairman. The recommendations of this committee will be found elsewhere in this issue. They are of a highly practical nature, and as employers were strongly represented on the committee, it may reasonably be hoped that many firms will adopt them. Quite apart from the educational advantages which may be expected to result from their adoption, there can be no doubt that other advantages will follow. A workman who recognizes that his efforts may gain him a better position, or even place him in a post of trust, is likely to exert himself in the interests of his employers; and any scheme which tends to unify the interests of employer and employé, and thus to reconcile the hostile feeling which so often exists between them, will undoubtedly cut at the root of one of the most serious evils of our industrial system.

Illustration of Engineering Lectures

The optical projection of lantern slides, as an aid to class teaching, has many advantages; but where diagrams of complicated machinery are involved, the student has insufficient time to copy the details in his note-book, with the result that much of the value of this form of illustration is lost. For many years past Professor John Goodman, of the Yorkshire College, Leeds, has furnished his students with photographic prints of the lantern slides used to illustrate his lectures. The students paste these prints in their "final copy" note-books. They cost the college a little more than a halfpenny each. Process prints could probably be produced at a much cheaper rate.

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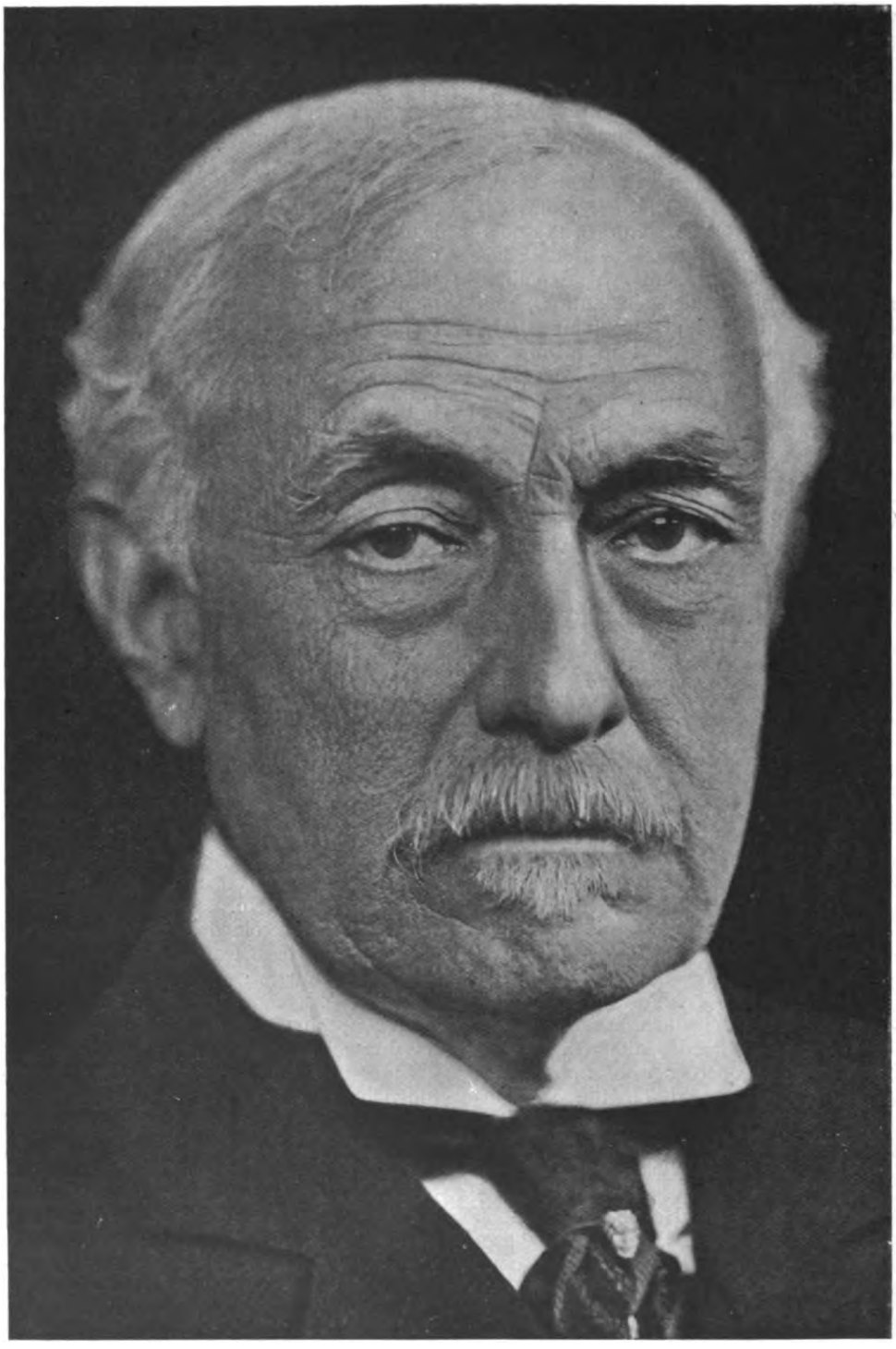

Photo by *George Newnes, Ltd.*

PROFESSOR W. A. TILDEN, D.SC., F.R.S.

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THE ROYAL COLLEGE OF SCIENCE, LONDON.

I.—THE NEW CHEMICAL LABORATORIES.

By Professor W. A. TILDEN, D.Sc., F.R.S.

Illustrated from the plans by Aston Webb, R.A.

THE new buildings of the Royal College of Science consist of a central block and two wings stretching east and west, facing the University of London and the Imperial Institute. In the centre will be situated the main entrance, and above this the Science Library, transferred from its present home in the Victoria and Albert Museum. Of the two wings, the east wing, with extensions in the rear, will provide for the accommodation of the entire chemical division of the college.

That the reader may understand fully the purpose of the arrangement which has been adopted, it is necessary to explain that the science of chemistry has, during the last forty years especially, undergone an immense development, in consequence of which it is no longer possible for one man to teach the whole subject effectively, at any rate with that intimate knowledge of detail which will alone enable him to lead advanced students forward. While there is still but one chemistry, the phenomena studied by the physical chemist, and hence the experimental methods employed, are different from those which occupy the student of "organic" chemistry, and these again are different from the methods, apparatus, and materials required in ordinary qualitative and quantitative analysis.

In any building, therefore, designed to accommodate students in various stages of progress, from comparatively elementary to the most advanced, including provision for a good deal of experimental research, these three main divisions, or rather aspects of the science, must be provided for. Accordingly, the new buildings contain complete suites of laboratories, lecture rooms, and accessory apartments, with accommodation for the teaching staff in the three divisions of—

1. General and analytical chemistry.
2. Physical chemistry.
3. Organic chemistry.

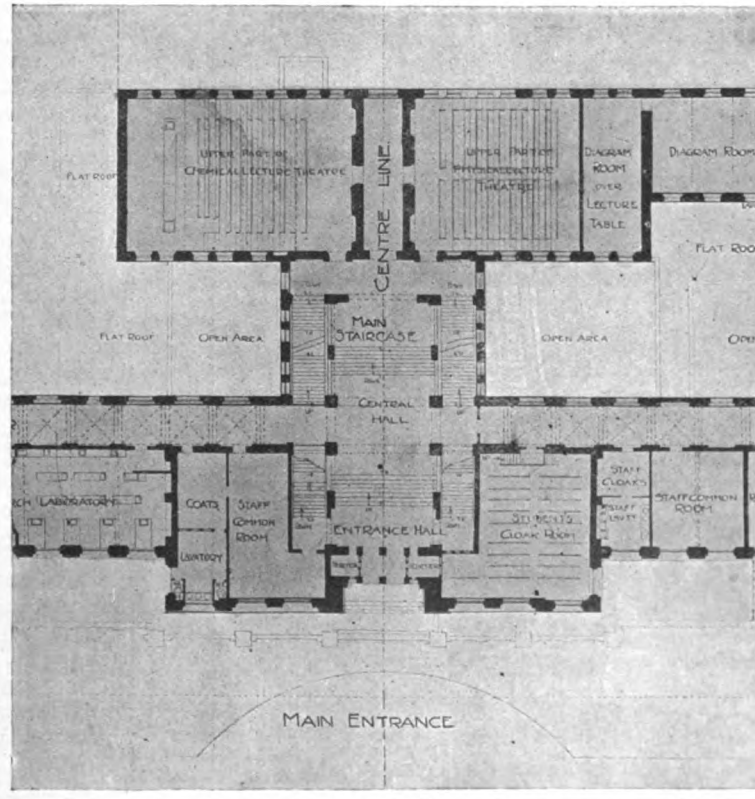

FIG. 1.—PART OF GROUND-FLOOR PLAN, SHOWING ENTRANCE HALL, MAIN STAIRCASE, AND LECTURE THEATRES.

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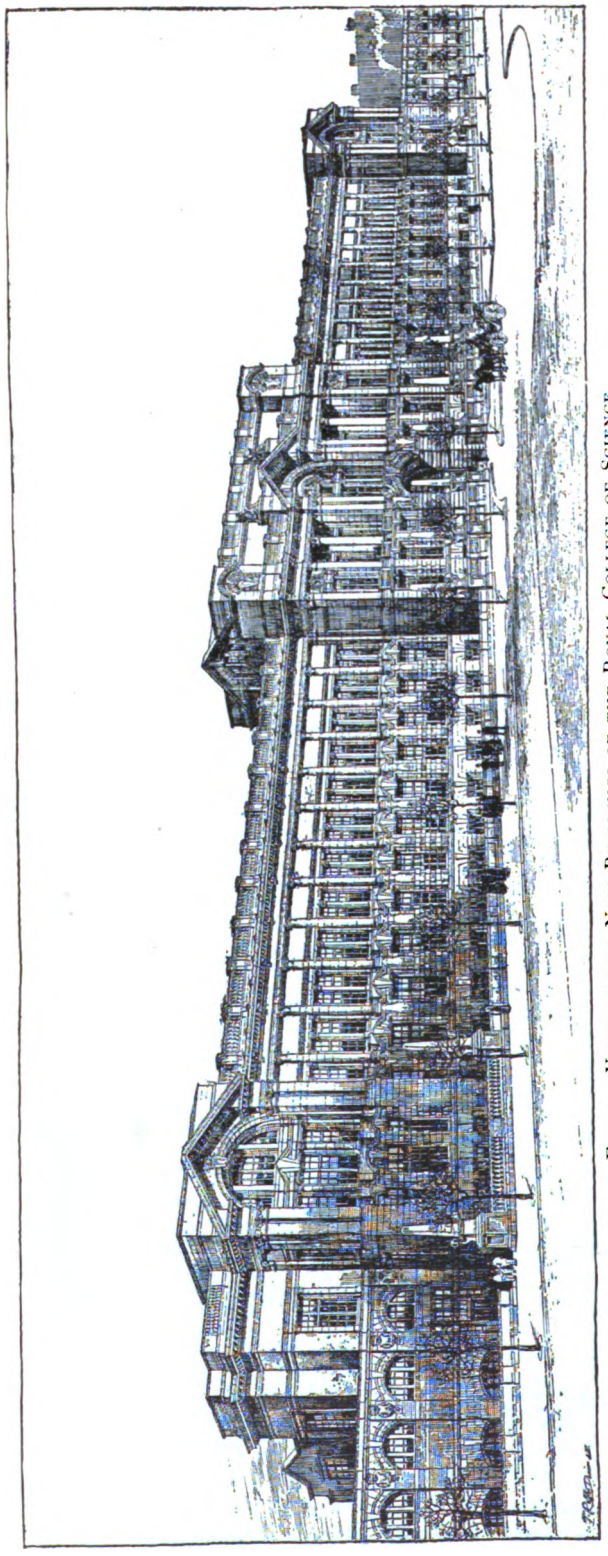

FIG. 2.—VIEW OF THE NEW BUILDINGS OF THE ROYAL COLLEGE OF SCIENCE.
By Aston Webb, R.A.

In addition to these divisions, each of which is so nearly complete in itself that it might at any time be worked by an independent staff, there is a store for apparatus and chemicals common to the whole, also a room for high temperature work and another for low temperature work, and an examination room, all of which are available for the purposes of any part of the chemical division. At the extreme east of the building will be a students' common room and a gallery for apparatus and models.

Entering the building by the chief entrance, the visitor will notice a number of faience tablets let into the walls, bearing the names of deceased men of science, chemists on the left, physicists on the right.

Ascending the first flight of stairs (see Fig. 1), the door of the lecture room is soon reached. This is of moderate size (60 × 40 ft.), giving accommodation for 150 persons seated, with a space to each of 3 ft. from back to front, and 2 ft. from side to side. A desk will be provided for each student. On special occasions the room will accommodate about double the number for whom the usual seating is calculated, as there is a broad space or gallery at the back of the descending tiers of seats. The lecture table extends along the whole front of the auditorium, so as to give plenty of room for long trains of apparatus. It will have the usual supply of gas, water, and electric current for experimental purposes, and the top will be covered with white tiles. Arrangements have been made for placing the demonstrator's lantern on one side of the seating space, so that the pictures may be projected on the back wall facing the audience. On the same wall are arrangements for suspending diagrams, which will be raised out of the way when the lantern is in use. There are also black-boards and a glass chamber for fumes, the latter accessible both from the

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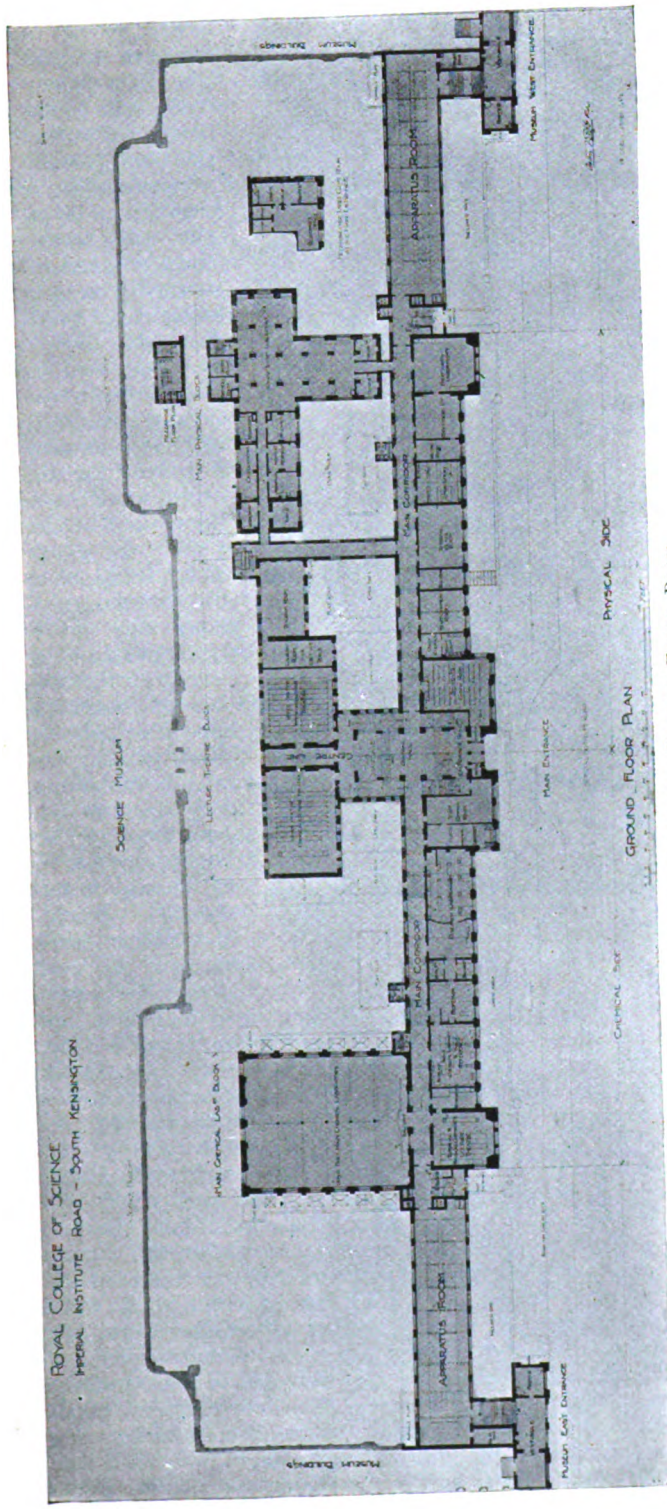

FIG. 3.—COMPLETE GROUND-FLOOR PLAN.

lecture room and from the preparation room at the back. The lecture room can be rendered completely dark when necessary by means of black blinds sliding in grooves on either side of each window. By day the room is lighted wholly from side windows. At night the lighting will be accomplished by clusters of incandescent lamps suspended over the lecture table and duly screened. There will also be a pair of arcs suspended in the middle of the room. Adjoining the lecture theatre is a room for the preparation of lecture experiments, for the storage of diagrams, and for cleaning apparatus.

Supposing the visitor to have entered by the students' door at the back of the theatre, and to have descended the steps of the auditorium, he is now on the level of the lecture table; and by passing through the door at the back, and leaving on one side a private room for the demonstrator, and a room for storing the glass vessels and fitted apparatus required in the lectures, he finds himself in the corridor which runs the whole length of the lower ground floor (See Fig. 4). This is below the level of the road, but occupants of the rooms in front look out into a spacious area which separates the building from the pavement. Proceeding eastward along this corridor, and leaving on the left the stores and a series of rooms devoted to the use of the demonstrators and the lecturer in physical chemistry, the entrance to the large laboratory is reached. This is an apartment 95 ft. by 75 ft., and 33 ft. high, which occupies ground at the back of the range of buildings facing the street. It is lined with white glazed

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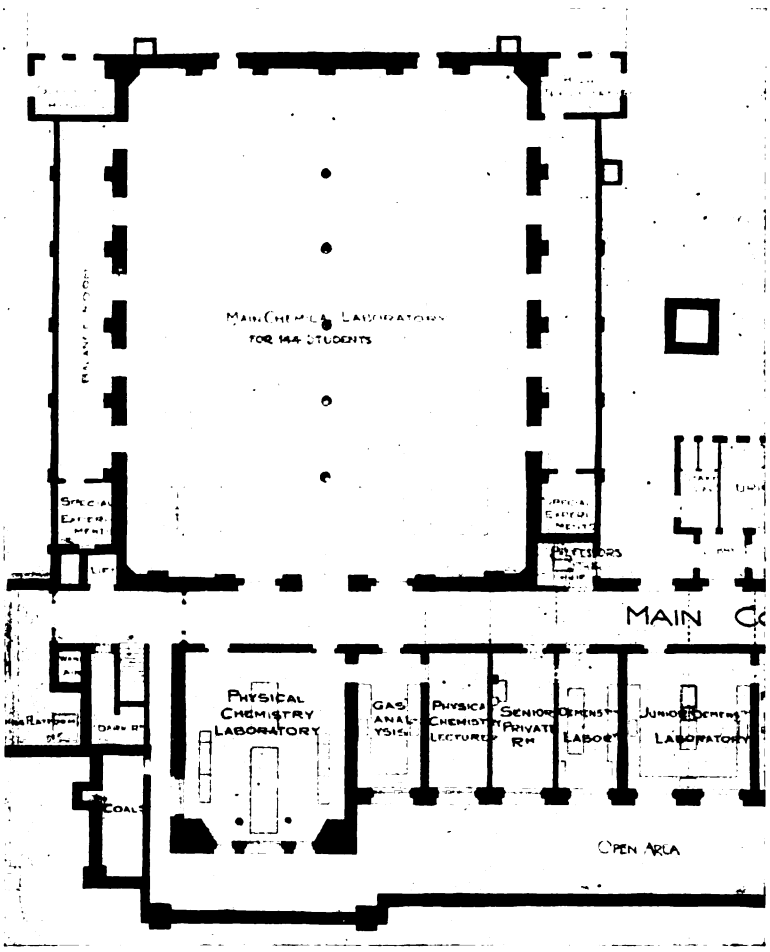

FIG. 4.—PART OF BASEMENT PLAN, SHOWING MAIN CHEMICAL LABORATORY.

brick, with a dado of green running shoulder-high round the whole of the laboratory. It may be mentioned here that this is the material used throughout the building, the object being to secure as much light as possible, and at the same time to cover the walls with a surface which can be completely cleansed by washing with water, and which is incorrodible by the action of steam or fumes.

The main laboratory provides working places for 144 students and four demonstrators. The benches are arranged in blocks of four, each place having 5 ft. run from left to right, and is fitted with a small closet supplied with sulphuretted hydrogen and ventilated by means of a down-draught shaft; also with coal gas, water, drainage, and electric light, with the usual drawers and cupboards below. The average floor space in the laboratory is nearly 50 sq. ft. for each student. The floor is covered with wood blocks set in concrete, and contains a complete set of channels for laying gas and water-pipes, etc., and for conveying the open troughs by which the waste liquids from the working tables are delivered into the drain. By day, the laboratory is lighted by means of tall windows on three sides of the room; the fourth side, being next the corridor, is provided only with a small gallery, on a level with the professors' rooms on the floor above, from which the whole laboratory may be viewed. In a laboratory so large it is necessary to bring fume-chamber accommodation and balances as near as possible to each worker. Accordingly, along the whole east and west sides extend two rooms 10 ft. wide, accessible from the laboratory by means of glazed swing-doors, and lighted from above, in which the balances will be placed. Between these doors, on the laboratory side, are fume chambers lined with white glazed brick, and provided with gas, water, and steam. In order to make use of fume chamber or balance, therefore, no student will require to travel more than half the width of the laboratory, a distance of about 38 ft., while the greater number are much nearer. At each of the four corners of this building is a small room, of which one, at the south-east corner, is entered only from the outside. It will be used for the manufacture and storage of the sulphuretted hydrogen, which is thence distributed to the laboratory. At the south-west corner is a room marked "High

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Temperatures," in which will be placed gas furnaces and muffles, as well as an electric furnace, for which a special supply of current will be laid on. The other two rooms are for analytical work—one for electrolysis, the other for water analysis. Steam ovens will be fixed to the north and south walls, and a small dais in each corner will raise the demonstrators' desks and working tables above the general level.

Returning to the corridor, the doors immediately opposite lead into the physical chemistry laboratory, 30 feet by 35 feet in dimensions. The details of the equipment of this room are still under consideration, but provision will be made for all those operations which are now employed by chemists for the determination of melting and boiling points, of specific heats, of conductivity, etc. An adjoining room on one side provides for gas analysis, and a dark room on the other for the use of the spectroscope, polarimeter, and photometer.

The floor above contains a series of rooms facing the street. Proceeding from the west, the first room is the research laboratory, in which a small number of senior students will work under the immediate supervision of the professor. The chief apartment is divided by a glass partition into two parts, of which one will be fitted with working benches of the usual kind, with operation tables for distillations, etc., and the other will provide floor space for apparatus which may require to be moveable and accessible on all sides. The mercury pumps, for example, and steam calorimeter will find a place here. The laboratory is connected with the professor's private room by a short passage, flanked on one side by a small dark room, and on the other by a small balance room. From the private sitting room or study a door leads into the library of reference (see Fig. 5), containing the principal chemical journals and the larger text-books and dictionaries. It is entered from the corridor, and will be open to students in the chemical division during working hours, under proper regulations. Adjoining the library is a small lecture room and preparation room for the use of the class in physical chemistry, and for other classes held in connection with the laboratory work. Seats are provided for fifty persons. On the opposite side of the corridor, doors lead into a balcony which overlooks the main laboratory and affords a bird's-eye view of the whole of the workers below. The floor above, called

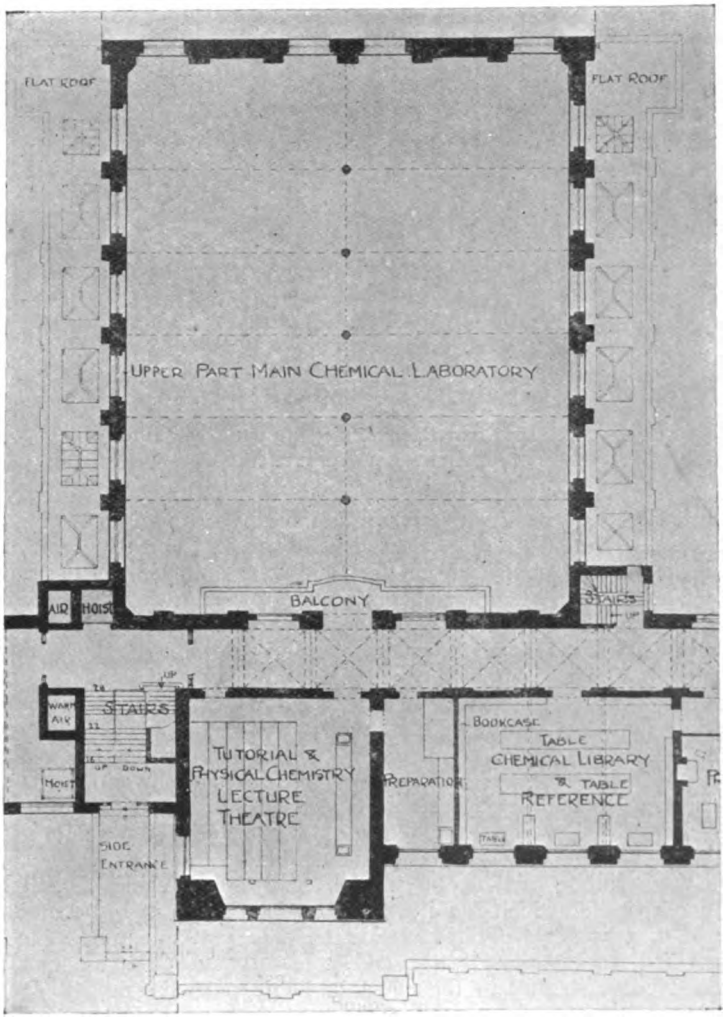

FIG. 5.—PART OF GROUND-FLOOR PLAN.

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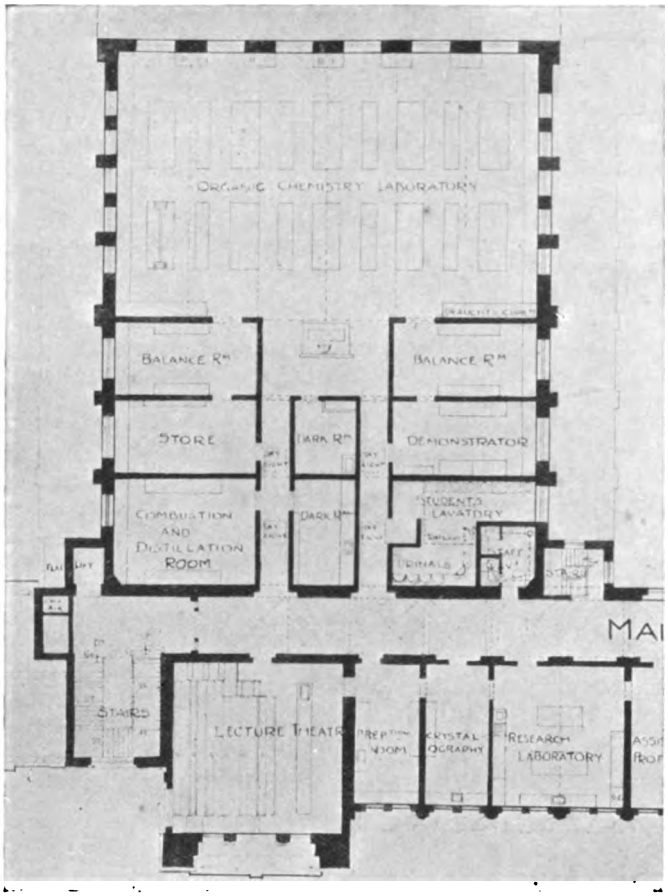

FIG. 6.—PART OF FIRST-FLOOR PLAN, SHOWING ORGANIC CHEMISTRY LABORATORY.

the first floor, is wholly devoted to "organic" chemistry (see Fig. 6). The general arrangements are obvious from the plan, but a few of the special arrangements require to be mentioned. The laboratory occupies exactly half the area of the main laboratory which is below. Working benches are provided for 40 students, and in this case the fittings differ from those of the large analytical laboratory, inasmuch as more space is needed for each worker. To provide for this there is an operation table, as shown in the plan, between each block of work-benches and the next, and on this table distillations will be carried out as well as any other operation which requires an extended train of apparatus. The operation table is provided with gas and water, and it has a raised edge, so that in the event of liquid being spilt it will not run on to the ground, but may be swept down a central groove to the drain. The whole is covered with sheet lead. Each working place will be supplied with gas, water, electric light, and a pipe connected with one of a number of water pumps in the corner of the room, by which reduced pressure may be obtained for filtration and other purposes. One of the rooms will be provided with an iron chamber, in which operations with sealed tubes which are liable to explode can be carried on. In the research laboratory there will also be an ice safe and ice breaker. It is also contemplated to set apart one room in which distillations of ether and other very volatile and inflammable liquids can be carried out by electric heaters, thus avoiding the proximity of flame. The lecture room is of the same size as the physical chemistry lecture room, over which it is situated, and is in like manner provided with a room for preparing experiments and keeping specimens. Next in order is a small room for crystallographic work. The private room and laboratory for the assistant professor follow, and a room for storing diagrams.

On the same floor are several rooms, situated at the back over the chief lecture theatre, which will serve as the photographic department of the college. Instruction in photography is at present given to about a dozen students of the chemical division annually. The new arrangement will provide for about three times that number, as well as accommodation for the teacher of photography and for some amount of research in connection with photographic action.

The top floor of this wing contains in the front a large examination room in which arrangements will be made for the examination of 100 candidates in practical chemistry at one time. In fitting this room for the purpose, the aim has been to provide for each candidate everything that is required in all ordinary work at the place assigned to him. There should therefore be very little

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movement in the room while the examination is proceeding. Some of the working tables have been in use at the university for the last two years and have been found satisfactory. In the new rooms a large number of balances, steam ovens, distilled water taps, and fume chambers will be placed along both walls, so as to be close to the students, whose work places will be arranged down the middle of the room, 50 facing east and 50 west.

Only one other department remains to be mentioned, and that is the one provided for experiments at low temperatures. A room is reserved in the lower ground floor below the main entrance, which will be provided with a gas engine or other motor, and compressors for the production of liquid air in quantity sufficient for its application to purposes of either demonstration or research.

The building is now approaching completion, but many months will be occupied in the final arrangement of fittings and apparatus, the details of which in many parts are still under consideration, having been purposely deferred in order that advantage may be taken of the very latest experience. Enough has been said to show that when finished the new building will take its place among the most complete chemical institutions in the world.

II.—THE NEW PHYSICAL LABORATORIES.

By Sir ARTHUR W. RÜCKER, K.C.B., D.Sc., LL.D., F.R.S.,
Principal of the University of London.

THE Royal College of Science, with which is incorporated the Royal School of Mines, is a Government institution which has been situate at South Kensington since the year 1881. There are about 300 students, of whom half are Government scholars, and the other half fee-paying students who have for the most part entered the Royal School of Mines.

The building in which it is housed is architecturally very beautiful, but it was originally designed as a chemical laboratory only, whereas for many years the Departments of Physics, Chemistry, Mechanics, Mining, Metallurgy, Zoology, and Botany have all been crowded into it. When the large grant for Government Buildings was made by Parliament some few years ago, one of the objects to which it was to be applied was the enlarging of the buildings of the Royal College of Science. It was then determined to provide buildings on an adequate scale for physics and chemistry, leaving the other Departments to expand into the space thus left vacant in the existing building. The site chosen is that opposite the University of London, which is now housed in the Imperial Institute Buildings, and the architect, Mr. Aston Webb, though not in any way competing with the more imposing structure which already exists, has made certain features of the new buildings echo, as it were, those of the Imperial Institute. Subject to the architect, the general arrangements of the physical laboratories were designed by myself. All the details (exclusive of the fittings), down to the positions of the gas-brackets and electric lights, were planned before the rooms were built. Owing to my resignation of the Chair of Physics, in 1901, the proposed arrangements have been submitted to the very competent criticism of my successor, Prof. Callendar, F.R.S. I am glad to know that he has been able to accept the plans, practically with no change; but the grave responsibility of advising as to the details of the fittings will rest with him. The task could not be in better hands. I should like to add that I received very valuable help from the Assistant Professor of Physics, Mr. W. Watson, F.R.S.

Confining our attention, therefore, to the physical laboratory, it is sufficient to say that the building consists of a range of rooms facing Imperial Institute Road, and of a secondary building, behind the first, in which many of the laboratories are placed. The front part of the building is protected from the road by a deep area and contains a good basement, first and second floors, together with an upper floor which is to be shared, for examination purposes, between the College and the University of London.

On entering the central door the student passes through a hall provided with the necessary cloak-rooms, etc., and then reaches

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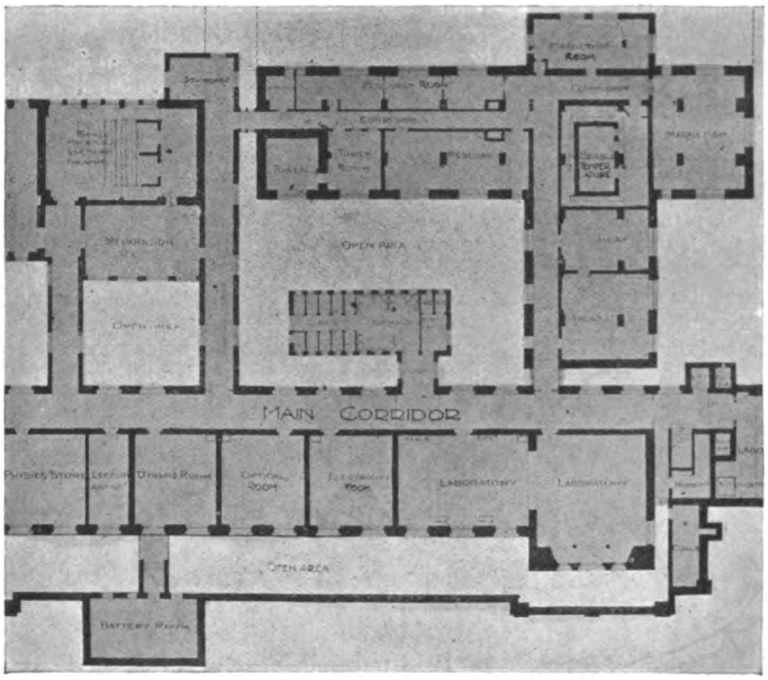

FIG. 7.—PART OF BASEMENT PLAN, SHOWING OPTICAL AND ELECTRICITY ROOMS, &c.

a broad passage, from which the physical lecture-room is entered on the right and the chemical lecture-room on the left (Fig. 1). The physical lecture-room is designed to hold 200 students with comfort, and the arrangements are planned so that the apparatus for two lectures can be set up simultaneously, without mutual interference. There are two lantern screens, in front of which diagrams can be suspended from a loft over the lecture-table. The portion of the room behind the lecture-table is lower than the rest, an arrangement which will reinforce the lecturer's voice. Special provisions have been made to render the acoustic properties as good as possible.

The basement of the front part of the building contains, beyond the area, a secondary battery-room, and behind it the optical and electrical laboratories (Fig. 7). They display all the main features of the arrangements in most of the other rooms, inasmuch as it was decided that the type of the fittings should be as generalised as possible, so that if particular apparatus becomes antiquated the rooms may nevertheless serve for newer forms. For this purpose slate shelves at table height have been placed at certain parts of the walls, and gas and electric light, as well as electrical power, have been led to each of them. The students' tables can be placed close to these shelves in such positions as may be found convenient, either at the side, in which case the table would generally be in a window, or in front, in which case it would project into the centre of the room. Stones, isolated from the floor, have been inserted at convenient places for carrying instruments which should not be shaken, and round the rooms baulks of timber have been attached to the wall, to which apparatus can be screwed or from which it can be suspended. Spaces have been left in the wall for carrying the electrical leads from room to room, and a projecting brick a few inches above the floor is arranged to carry pipes which, if of lead, might be bruised if placed upon the floor itself. Small windows connect the various rooms, terminating in a photometry-room, so that a beam of light can, if desired, be sent through the whole range of rooms.

Above this is the Professor's laboratory and private sitting-room and a range of subsidiary laboratories.

The second building, which has been already referred to, is iron-free and is carefully protected from vibration. It is only connected with the front building by very light corridors to check the transmission of shocks, and the whole is surrounded by a trench filled with peat to ward off the effects of surface vibrations.

In the basement are a number of rooms devoted to heat and magnetism. It was impossible to have a constant temperature room below ground, as the water level is not very deep, but a special room for constant temperature has been designed, the walls of which are double (Fig. 7.) Inside it there is an inner room, separated from the walls of the external chamber by a passage which runs all round

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it, lit from above through glass by electric light, and with a window through which instruments can be read from a steady stand without entering the inner room itself. The whole is, of course, protected by an air-lock. As, in cold weather, the diurnal range will probably be very great in the surrounding building, it is possible that even precautions such as these may not be absolutely satisfactory, but artificial heating or cooling can be readily applied.

Above this range of rooms is the senior physical laboratory (Fig. 8), through which pass pillars to support the junior laboratory, which is above it. These pillars have been utilised to carry steady shelves, and will enable students working in the middle of the room to bring their tables close to a galvanometer or other similar instrument, which is itself supported by the pillar. A room for the Assistant-Professor, calculating rooms, and small research laboratories are attached.

The largest room is on the next floor. It is the elementary laboratory (Fig. 9), and is T-shaped, the main portion being about 120 feet long with a projecting arm about 50 feet long. The arrangements in this are very special. The pillars above described carry arches, the spaces between which are filled up with coke to a distance of some inches above the top of the arch. The tables are carried on brick foundations, protected from vibration by this coke. Above the coke is a concrete floor, which is separated from the brick walls which are to carry tables by a space of one inch, thus protecting them, as far as possible, from vibrations produced in the room itself. At the places where the tables are placed the concrete is two inches higher than elsewhere, thus preventing any risk of flooding, which is also guarded against by the fact that the channels in the floor which carry the gas and water-pipes are themselves provided with drains.

Each table is fitted for ten students, who will be in charge of one student in training as a teacher. All the tables are separated by a space about 12 feet wide, in which

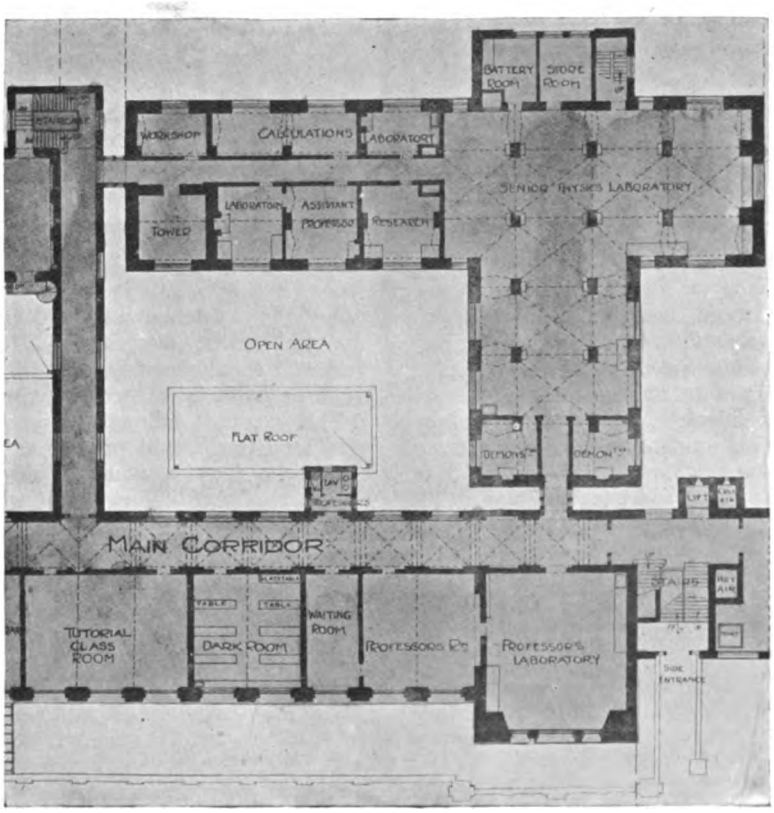

FIG. 8.—PART OF GROUND-FLOOR PLAN, SHOWING SENIOR PHYSICS LABORATORY.

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other apparatus can be set up. On the wall behind each table are shelves for carrying balances and the like. Each table and its surroundings thus constitute a small physical laboratory, the arrangements of which are repeated again and again. Running down the centre of the roof is a wooden passage from which wires, pendulums, etc., can be suspended.

There is also a tower, 85 feet high, for experiments on high pressures, etc.

The ventilation is to be by means of air, warmed, cleaned, and forced into the rooms on the plenum system.

This short sketch may, perhaps, give a general idea of the arrangements of the laboratory, which is one of the largest, if not the largest, in this country, devoted to physics

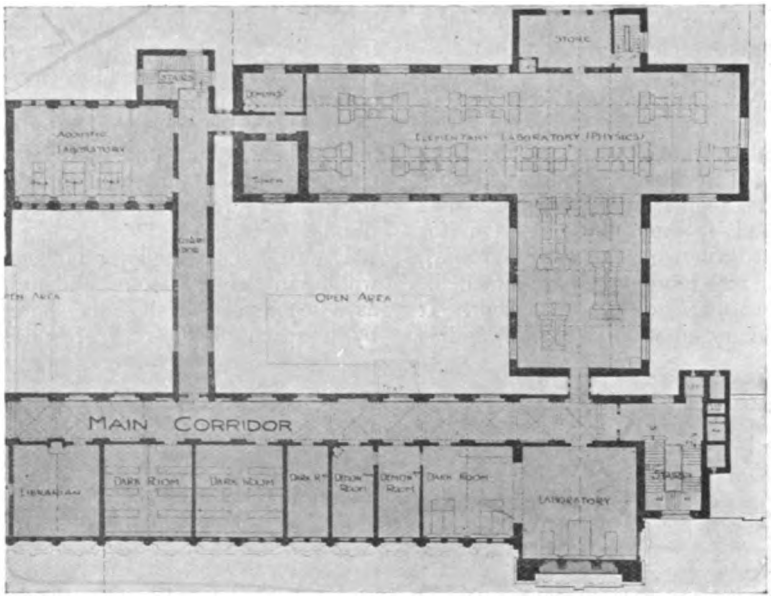

FIG. 9.—PART OF FIRST-FLOOR PLAN, SHOWING ELEMENTARY PHYSICS LABORATORY.

The store-room, furnished with a lift, is approached from the room itself, so that any student requiring glass, rubber tubing, etc., can obtain it without leaving the room.

This large laboratory is supplemented by two others for students of a rather more advanced type, and by a number of dark rooms, though it can itself be darkened if necessary.

alone. It is calculated to hold 150 elementary and about fifty senior students, all working simultaneously, but this number could probably be exceeded if necessary.

The chemical laboratories are also on a very large scale, and present many features of interest, but I confine my description to the part of the building with which I am best acquainted.

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THE ELECTRIC AND MAGNETIC PROPERTIES OF ALLOYS OF IRON.

By Professor W. F. BARRETT, F.R.S., Professor of Physics at the Royal College of Science, Dublin; and W. BROWN, B.Sc., Lecturer on Electro-Technology in the same Institution.

FOR several years past the authors have been engaged in the investigation of the physical properties of an extensive and unique series of alloys of iron, prepared with great care by Mr. R. A. Hadfield, M.Inst.C.E., at the Hecla Steel Works, Sheffield.

In preparing the specimens for examination, a great variety of alloys of iron were cast into ingots. Of these latter, 110 were successfully forged into bars, and then, after being heated to a bright red (about 900° C.), were rolled into cylindrical rods of about 0·5 cm. diameter. After being straightened, these rods were forwarded to the Royal College of Science, Dublin, where their electrical and magnetic properties were tested. The rods were then sent back to Sheffield, where they were carefully annealed in an E. and W. position, at a temperature of 1,000° C., the cooling occupying 100 hours, or about four days and nights; they were then returned to Dublin, where their electric and magnetic properties were again carefully determined by the authors. The chemical analyses of the alloys were conducted in the laboratory attached to the Hecla Works.

PROF. W. F. BARRETT, F.R.S.
Photo by Barclay Bros.

The resistivities of the specimens were determined by observing the drop of potential due to a constant current flowing through each rod, and comparing this with the drop of potential produced by the same current flowing along a standard rod of iron or copper. The length of each rod having been measured, its volume was found by water displacement. A long glass tube, closed at one end, was used for this purpose, the tube being 1 cm. in diameter, and graduated in tenths of a c.c. The mean sectional area of each rod was calculated by dividing its volume by its length.

The curves in Fig. 1 exhibit at a glance the resistivities (or specific electric resistances) of various alloys of iron. Each curve corresponds to an alloy of iron and one other element, the name of the latter being attached to the curve. The percentage of the added element is plotted horizontally, while the resistivity of the alloy, in microhms per centimetre cube at 18° C., is plotted vertically. The three horizontal broken lines near the bottom of the figure indicate the resistivities of iron when the impurities contained amount to 1 per cent., 0.5 per cent., and 0·1 per cent. respectively.

An inspection of Fig. 1 shows that, of all the alloys examined, those containing *tungsten* differ least from pure iron. The change produced by the addition of even the smallest quantity of carbon is strikingly shown. In fact, other things being equal, a determination of the resistivity affords a rapid and simple method of estimating the amount of carbon present in a sample of steel, by an inspection of Fig. 1. It should further be noticed that the increase in the resistivity is not directly proportional to the percentage of an element added to pure iron; the first increment produces by far the greatest effect. Thus the addition of 1 per cent. of nickel to pure iron nearly doubles the resistivity; on increasing the amount of nickel contained, from 10 per cent. to 20 per cent., the resistivity increases only in the ratio of 40 to 35.

The increased resistivity produced by

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alloying iron with another metal is not due to the greater resistivity of the added metal. On the contrary, an alloy of *very high* resistivity can be produced by adding to iron an element of *much lower* resistivity than the iron itself. Thus, the resistivity of aluminium is equal to about 2·2, while that of iron is equal to about 10; an alloy of iron with 5·5 per cent. of aluminium has a resistivity equal to 70. In fact, the resistivity of an alloy appears to have no connection with the resistivities of its constituents.

Table I. gives the resistivities of a number of composite alloys of iron. In all cases the resistivity is high, in some instances remarkably so. Thus, an alloy containing 69·40 per cent. of iron, 1·18 per cent. of carbon, 25·00 of silicon, and 5 per cent. of

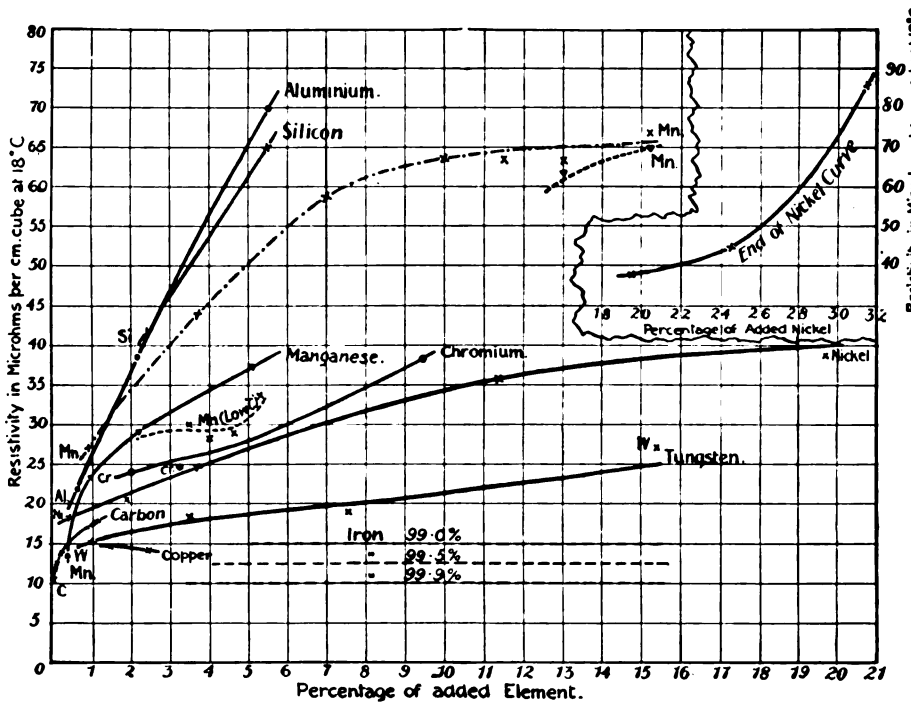

FIG. 1.—RESISTIVITIES OF ALLOYS OF IRON.

TABLE I.

RESISTIVITIES AND TEMPERATURE COEFFICIENTS OF COMPOSITE ALLOYS OF IRON.

Percentage Composition.	Resistivity in microhms per cm. cube.	Temperature coefficient.
Fe., 99·89; C., 0·028; Si., 0·07; S. & P., 0·009 (pure Commr. Iron)	10·47	0·006
,, 96·59; ,, 0·59; Cu., 2·5; Mn., 0·32	13·5	0·00457
,, 97·36; ,, 0·68; ,, 1·6; ,, 0·36	13·9	0·00418
,, 95·93; ,, 0·17; ,, 2·9; ,, 1·00	16 2	0·00366
,, 95·26; ,, 0·04; ,, 3·7; Al., 1·00	20·8	0·00280
,, 93·77; ,, 0.48; ,, 2·0; W., 2·00 Cr. 1·75	31 6	0·00204
,, 94·26; ,, 0·22; Al, 5·5; Si., 0·2	74·6	0·00063
,, 97·50; ,, 0·50; Ni., 1·00; Mn., 1·00	28·6	0·00150
,, 79·70; ,, 0·80; ,, 14·50; ,, 5·0	83 0	0·00109
,, 75·40; ,, 1·00; ,, 19·00; ,, 5·0	90·6	0·00104
,, 69·40; ,, 1·18; ,, 25·00; ,, 5·0	97·5	0·00085
,, 67·48; ,, 0·70; ,, 31·00; ,, 0 82	86.5	0·00090
,, 67·90; ,, 0·60; ,, 30·00; ,, 1·50	89·0	0·00077

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manganese, has a resistivity equal to 97·5 microhms per centimetre cube, a value nearly ten times as great as that of pure iron, more than three times that of German silver, and more than twice that of platinoid. Its temperature co-efficient (*i.e.*, the increase in resistance per degree C. rise of temperature for each ohm of its original resistance) is fairly small, being equal to 0·00085; while that of copper is equal to 0.004, that of German silver is equal to 0·002, and that of platinoid is equal to 0·0002. The above alloy is easily drawn into wire: it appears to undergo but little change in heating, and is not an expensive product. Another alloy, containing 15 per cent. of nickel and 5 per cent. of manganese, has already been put on the market; it was originally called *rheostene*, but is now known as *resista*. It has a resistivity equal to 83 microhms per centimetre cube, and a temperature co-efficient of 0·00109. Six years ago the whole of the resistance coils used in the electric installation and lecture theatre at the Royal College of Science, Dublin, were replaced by coils of rheostene, and up to the present no depreciation has been noticed. In certain circumstances, however, *thin* rheostene wires become brittle and perish.

In all cases annealing reduces the resistivities of iron alloys. A rod of one particular alloy, containing 14 per cent. of nickel, 5 per cent. of manganese, and 2 per cent. of aluminium, had a resistivity of 89 microhms per centimetre cube before annealing; while the same specimen, after annealing, had a resistivity of 48 microhms per centimetre cube.

The presence of carbon in composite alloys of iron has a marked effect on the resistivity. The curve –·–·–·– (Fig. 1) marked Mn. refers to a manganese alloy rich in carbon, while that marked *Manganese* (*Low* "C") refers to an alloy poor in carbon.

We are unable to give a complete physical explanation of the results described above. At present the mechanism of electrical conduction is unknown, and therefore the peculiarities exhibited by alloys can scarcely even be made the subject of speculation. We have found, however, that certain general laws may be formulated. For *small* percentages of an added element, the change in the resistivity is roughly proportional to the percentage of the element added. Thus, from the experimental data given above, we may calculate the increase in the resistivity produced by the addition of 1 per cent. of various elements, and so obtain the figures in the first column of Table II. The second and third columns give the specific heats and the atomic weights of the various added elements.

TABLE II.

Added Element.	Increase of restivity for 1 per cent. of added element.	Specific Heat of added element.	Atomic weight of added element.
Tungsten .	2	0·035	184
Cobalt . .	3	0·107	59
Nickel . .	3·5	0·109	59
Chromium	5	0·1 (?)	52
Carbon .	5	0·160*	12
Manganese	8	0·122	55
Silicon .	13·0	0·183	28
Aluminium	14	0·212	27

* Specific heat of carbon in the form of graphite.

From this table it will be seen that the increase in the resistivity produced by the addition of 1 per cent. of an added element is roughly proportional to the specific heat of the added element, and inversely proportional to the atomic weight of the latter. Thus, 1 per cent. of aluminium added to iron produces an increase in the resistivity which is seven times as great as that due to the addition of 1 per cent. of tungsten; the ratio of the specific heats of aluminium and tungsten is equal to 6·07.

We have also found that the electrical conductivities of these alloys go hand-in-hand with their thermal conductivities, a result which seems to show that, in a metal, electrical conduction and the conduction of heat are closely related phenomena.

In the determination of the magnetic properties of these alloys, complete **B** and **H** curves were obtained for nearly every specimen, the maximum value of **H** being 45 C.G.S. units. The specimens having been made in the form of rods about a metre long and half a centimetre in diameter, the magnetometer method was necessarily employed. The rod under test was supported, in a vertical position, within a magnetising solenoid about 120 cms. long; the upper pole of the rod was placed at a horizontal distance of about 45 cms. from the magnetometer needle. The direct effect of the solenoid on the magnetometer needle was neutralised by a compensating coil in the main circuit, while the magnetising effect of the vertical component of the earth's field was neutralised by a small independent current circulating through a single layer of wire wound round the

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solenoid. The value of the earth's horizontal component was accurately determined, and checked from time to time during the course of the experiments.

The permeabilities obtained for a number of alloys can be seen at a glance on referring to Fig. 2. The curve for nickel is particularly noteworthy. A small percentage of nickel scarcely affects the permeability, but if the percentage added is increased, a sudden fall in the permeability occurs when about 4 per cent. is reached, the alloy then becoming very feebly magnetic. A further increase in the percentage of added nickel produces little effect until about 25 per cent. has been added, when the permeability rises somewhat rapidly.

The first part of the manganese curve resembles the first part of the nickel curve, but the permeability subsequently falls to a lower point, becoming practically equal to unity for a 12·5 per cent. alloy of manganese. This alloy is therefore non-magnetic.

A remarkable feature in the magnetic properties of manganese steels is the part played by the presence of carbon in the alloy. In *low* manganese steels, *i.e.*, when the manganese does not exceed 3 or 4 per cent., high carbon reduces the permeability; but in *high* manganese steels, *i.e.*, when the manganese in the alloy exceeds

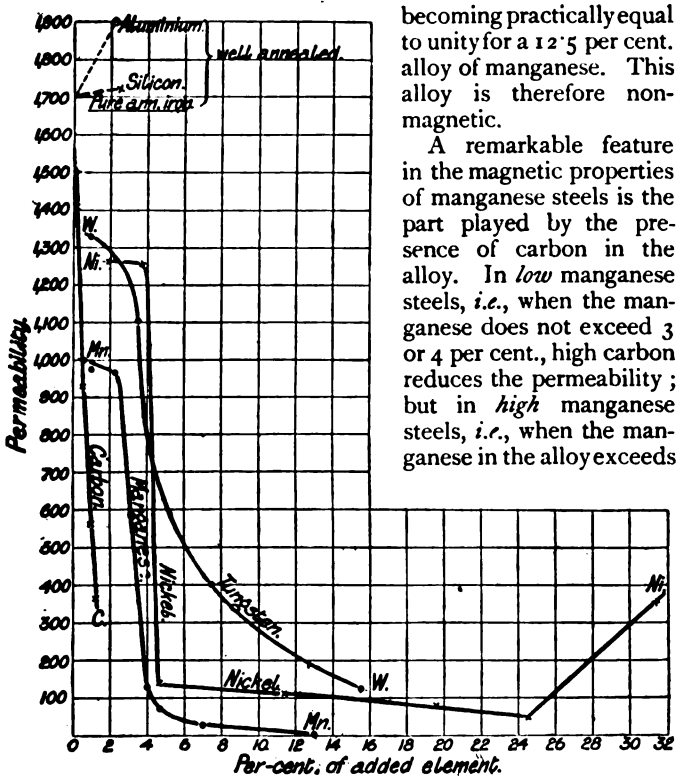

FIG. 2.—PERMEABILITIES OF SOME ALLOYS OF IRON.

TABLE III.

PERMEABILITIES OF NON-MAGNETIC, AND NEARLY NON-MAGNETIC STEELS, FOR A MAGNETISING FORCE OF 320 C. G. S. UNITS.

The permeabilities of these alloys decrease as the magnetising force is diminished. Cast steel has a permeability of about 400, and cast iron about 230, for the above magnetising force. Cast steel and cast iron have maximum permeabilities for a lower magnetising force.

Previous thermal Treatment.	Percentage Composition.	Permeability.
Annealed	Fe., 86·74; C., 0·26; Mn., 13·0;	3·55
,,	,, 85·77; ,, 1·23; ,, 13·0;	5·82
Un-annealed	,, ,, ; ,, ,, ; ,, ,, ;	1·00
Annealed	,, 84·64; ,, 0·15; ,, 15·2;	1·00
,,	,, 83·25; ,, 1·5; ,, 15·25;	4·23
,,	,, 80·96; ,, 1·54; ,, 18·5;	2·93
,,	,, 76·58; ,, 0·83; ,, 5·9; Ni., 14·44; Cu., 2·25	1·79
,,	,, 80·16; ,, 0·8; ,, 5·04; ,, 14·55;	1·18
Un-annealed	,, ,, ; ,, ,, ; ,, ,, ; ,, ,, ;	1·00
Annealed	,, 75·36; ,, 0·6; ,, 5·04; ,, 19·0;	1·63
Un-annealed	,, ,, ; ,, ,, ; ,, ,, ; ,, ,, ;	1·18
Annealed	,, 69·36; ,, 0·6; ,, 5·04; ,, 25;	1·27
Un-annealed	,, ,, ; ,, ,, ; ,, ,, ; ,, ,, ;	1·20
Annealed	,, 88·22; ,, 1.21; ,, 8·0; ,, 2·57;	1·27
,,	,, 79·35; ,, 1·4; ,, 10·25; ,, 9·0;	2·92
,,	,, 84·71; ,, 1·34; ,, 11·1; W., 2·85;	2·18
,,	,, 86·61; ,, 1·08; ,, 10·2; ,, 2·11;	1·20
,,	,, 78·12; ,, 0·88; ,, 17·5; Cr., 3·5;	2·81

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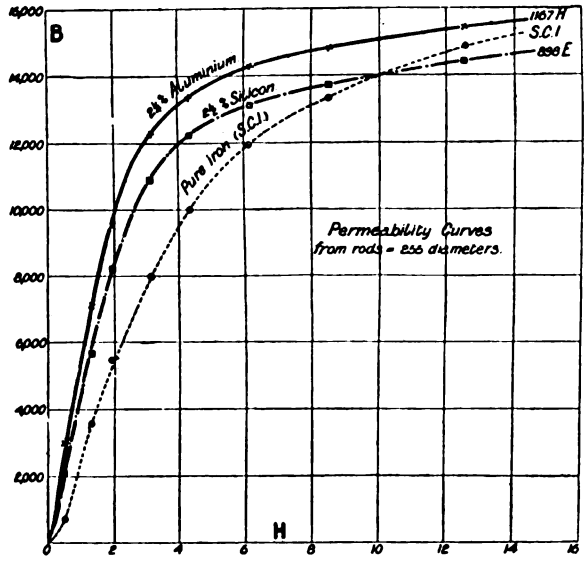

FIG. 3.—B.H. CURVES FOR PURE IRON (S.C.I.) AND ALLOYS CONTAINING ALUMINIUM AND SILICON.

markable are the magnetic changes produced in certain alloys of iron by the addition of a comparatively small quantity of another element. Thus the high-nickel steels are fairly magnetic, but the addition of 5 per cent. of manganese renders them completely non-magnetic, albeit a 5 or even 8 per cent. manganese steel is magnetic. An 8 per cent. manganese steel becomes non-magnetic on the addition of 2½ per cent. of nickel.

The extreme hardness of the manganese steels has prevented their general use, but an iron alloy containing 1·4 per cent. of carbon, 10·25 per cent. of manganese, and 9 per cent. of nickel is practically non-magnetic, and yet can be readily machined. Non-magnetic steel ships would be a great advantage in navigation, and these could now be made if the cost were not prohibitive.

10 per cent., an increase of carbon *raises* the permeability. The *hardness* of the manganese steels, as tested with the file, precisely agrees with their relative magnetic conditions, the steels with the smallest permeability being invariably the hardest.

Annealing produces marked effects on the permeability of iron alloys. Thus, an alloy containing 8·9 per cent. of chromium and 3·1 per cent. of manganese is highly magnetic when annealed, but practically unmagnetic when unannealed.

Table III. gives particulars of a number of practically non-magnetic alloys of iron. From this it will be seen how re-

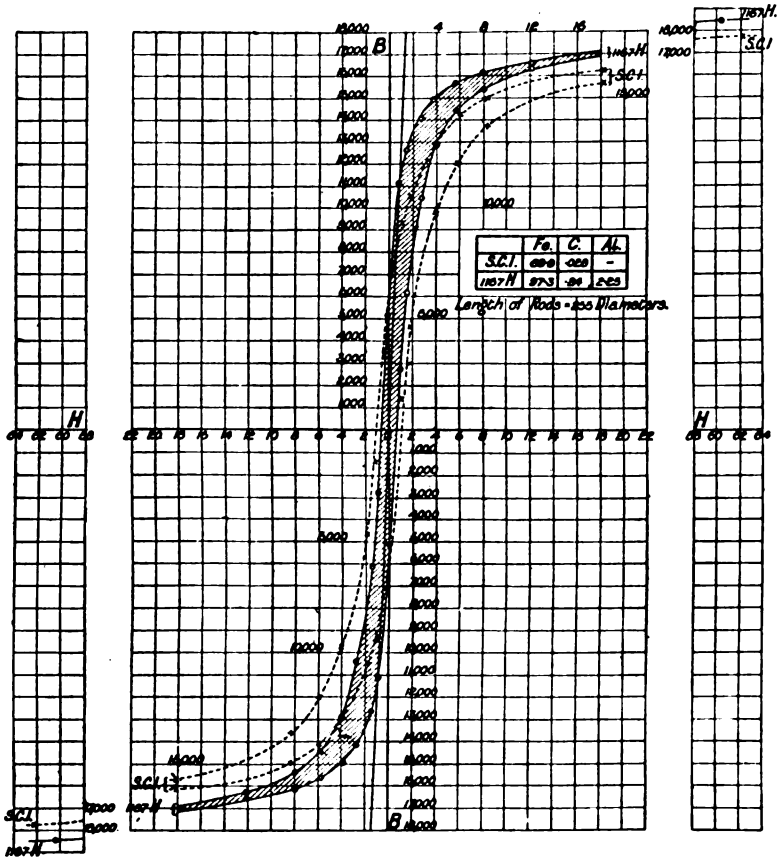

FIG. 4.—COMPLETE MAGNETIC CYCLES FOR PURE IRON (S.C.I.), AND AN ALLOY OF IRON CONTAINING 2½ PER CENT. OF ALUMINIUM.

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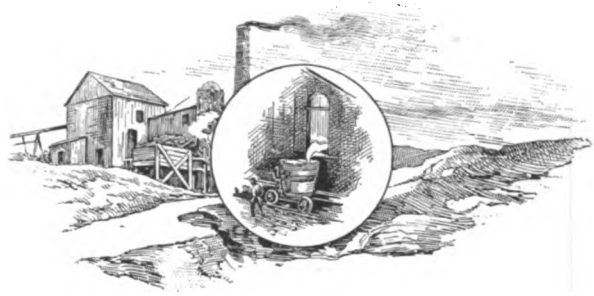
Unfortunately, many of the above non-magnetic alloys rust badly when exposed to moisture.

Not only is it possible to obtain non-magnetic alloys of iron, but we can obtain alloys which are much more magnetic than the purest iron. In Fig. 3 the **B.H** curves marked *pure iron* (S. C. I.) refer to Swedish charcoal iron ; in the same figure are included curves for alloys of iron, containing respectively $2\frac{1}{4}$ per cent. of aluminium and $2\frac{1}{2}$ per cent. of silicon. Both these curves lie well above that for pure iron for moderate values of **H**. The curve for the aluminium alloy remains above that for pure iron throughout its whole length.

While the permeability of the above aluminium iron alloy is much greater, its hysteresis losses are much less than those of pure iron. From Fig. 1 it will be seen that this alloy also has a high resistivity. These qualities should render it valuable as a substitute for iron or steel in the construction of armature-cores, pole-pieces, and transformer cores. In all these cases the magnetic flux is continually changing, with the result that energy is lost in demagnetising and remagnetising the iron, as well as in the production of eddy currents. These energy losses would probably be greatly diminished if the above aluminium-iron alloy were used : the first due to the low hysteresis, and the second due to the high resistivity of the alloy. Field magnets would also require less copper for winding, on account of the higher permeability of the alloy, and they might be made much lighter—a matter of importance in connection with traction motors.



GOING THROUGH THE SHOPS.

By JOSEPH G. HORNER, A.M.I.Mech.E.

THIS is a common expression which distinguishes the education of the articled pupil from that of the apprentice. It denotes the fundamental difference between the training of the latter in a trade, in one shop only ; and that of the former as an engineer, in the great group of shops which comprise, in their aggregate, the engineering works. The distinction is therefore of fundamental importance, and it is one that has existed for several generations. But recent movements are taking place which may result in breaking down, to some degree, this hard-and-fast distinction, though it is too early yet to gauge with much confidence their ultimate issues. These movements are a result, among many, of the important place which the technical schools are taking in the training of engineers. They also embody an effort to break down the close preserve of the articled pupil, and throw open the wider career of engineering to youths of special ability, who, through want of sufficient funds, are restricted to the narrow opportunities which apprenticeship affords. Thus, a pupil has to pay from £50 to £100 a year for his privileges—money which, in the case of an indolent youth, is thrown away. The apprentice is now seldom asked to pay any premium, and he is often not even indentured, so that his opportunities of learning a trade depend on his ability and behaviour, dismissal being the penalty of incompetency or insubordination.

But whatever the future may hold, it is a fact that, at the present time, there is

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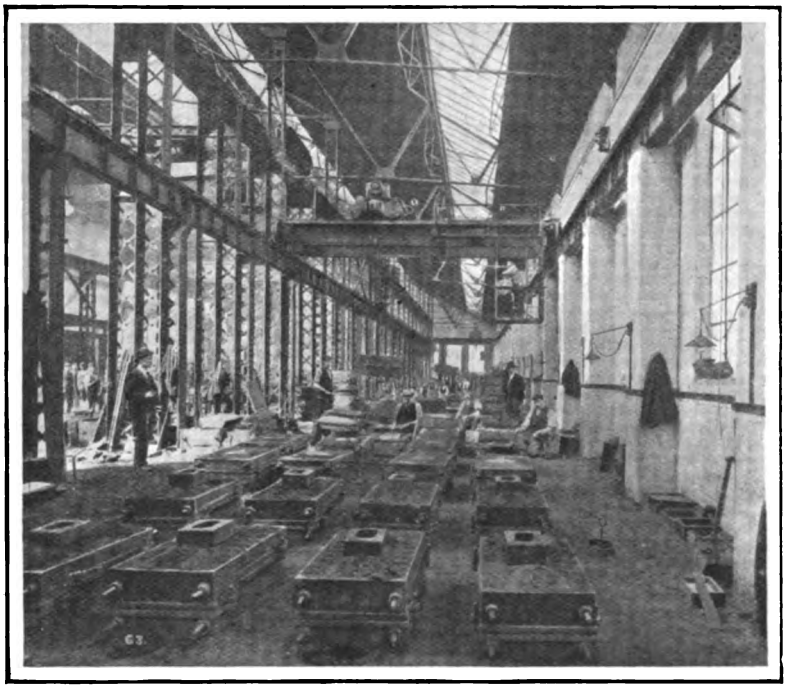
no middle course open between that of articled pupilage and apprenticeship in most works; and the ambitious youth, therefore, whose parents are without means, must forfeit the privileges which articled pupils enjoy. To such, however, the technical schools come as a boon, for in the best equipped of these, a youth gathers a knowledge of the practice of departments outside those in which his apprenticeship is passed, and also of the principles which underlie the practice of his own and other cognate trades. This, however, is beside our present subject, and need not be pursued further.

To "go through the shops" is the equivalent to walking the hospitals. For the pupil, like the medico, is not a passive observer merely, but an active participant, according to his knowledge and skill in the work of the department in which he happens to be located. He is, however, at liberty, under reasonable restrictions, to enter other departments besides that in which he is occupied for the time being, for the purpose of observing any special processes of interest, and of watching tests being made. Neither the apprentice nor the workman can ever do this, but they are rigidly confined to their own shops. As a rule, a pass from the foreman is required, if any work renders their entrance into another department necessary for a while.



FOUNDRY OF THE ENGLISH ELECTRIC MANUFACTURING CO., PRESTON
From a photograph, by permission.

Engineering practice! Think for a moment what is included in that, and say whether any other occupation, save that of medicine, demands knowledge of so varied and many-sided a character. It includes an intimate and workable knowledge of all the following separate and distinct occupations and crafts: Designing and drawing, pattern-making, carpentry, foundry work in iron and brass, smithing, boiler-making, plating, metal-turning: the work of hundreds of different kinds of machine tools, involving cutting, detrusive, concussive, rolling, bending actions, the work of fitting and erecting, of copper-smithing, tinmen's work, painting and varnishing, inspection and tests of materials and mechanisms, besides commercial knowledge as to prices, markets, and the rest.

And to back up all this practical knowledge, and prevent it from degenerating into rule of thumb, and from running wholly in the beaten tracks of precedent, some basis of scientific knowledge (and the more the better) is essential. You cannot deal safely with machinery of any kind without understanding something about the fundamental laws by which its action is governed; and as there is no natural force, and few materials, which the engineer does not press into his service, he must acquire at least a working knowledge of the properties and action of steam, air, water, electricity, of mechanical forces, of stresses and strains, of timbers, irons, steels, and many metals and alloys besides, and of numerous other substances that enter into construction. His knowledge must be at his fingers' ends, ready for instant use in

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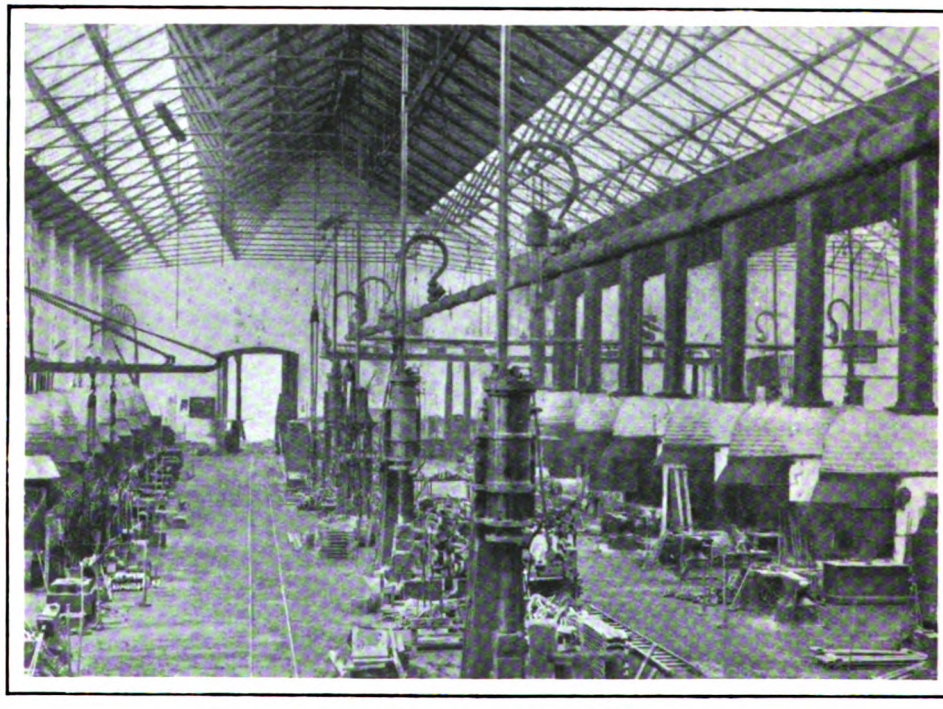
emergencies, which frequently occur where no books are available. Further, the pupil has to lay a good basis for his life's work in all these departments of knowledge within the space of from three to five years! How best to accomplish all this is one of the burning questions of the time.

It should be clear, therefore, that pupilage, to be successful, must be marked by strenuous effort. The idler is bound to go to the wall. The non-recognition of this fact has been the professional ruin of a good many pupils. I have known some, in my time, who have drifted right out of engineering into easier callings, while a good many have been glad to secure berths as second-rate draughtsmen. Years ago, even more than at the present time, a large proportion of pupils regarded themselves as professional idlers, privileged by virtue of their high premium and good connections. Employers, too, let them go along pretty much as they liked, provided only that they did not hinder the workmen. Good time-keeping was deemed of little or no account, nor was continuous application to work enforced. Things have much improved in these respects of late years, but loafing is still tolerated in most works, if the pupil is so inclined. The result is, that the future of a pupil depends mainly on his own efforts. The premium is paid simply in exchange for the privilege afforded by the big works of gathering knowledge of all the departments of engineering practice; but it does not include the obligation to impart set courses of information, akin to that of the schools. If a pupil is energetic, industrious, anxious to learn, and courteous to all alike, he is welcome to lay under contribution all the knowledge available in the whole works, and as much as he is able to assimilate in the time spent there.



Smithy of the Lancashire and Yorkshire Railway, Horwich.
From a photograph, by permission.

The list of departments given just now is one that is fairly typical of those which are comprised in large works. Some works, however, do not include all these, but on the other hand many factories are more comprehensive, including carriage and waggon departments, stamping shops, electrical and experimental departments, etc., besides which many of the large shops are subdivided into several groups, which increase in number with the size of the works, and with the growing specialization of its products. In any

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case, however, whether works are larger or smaller, it is obviously impossible for a pupil to occupy very much time in any one department, with so much to crowd into the three, four, or five years which his articles cover; and so a compromise is generally effected, as follows :—

A pupil is at liberty, by arrangement with the firm, to go through some departments in preference to others. He is, however, well advised to give chief attention to the drawing office, the pattern shop, machine shop, and turnery, and in most cases the foundry. Frequently, therefore, he will engage in the actual work of these only, and pay frequent visits to the others. Should, however, a pupil have a definite sphere of future life mapped out, then he will select those departments which it is desirable that he should know most intimately. And thus it may occur that boiler work will figure most prominently, or electrical construction, or crane building, or foundry work. I knew one pupil who took an engineering course while in training for a barrister in technical cases, and spent most of his time in the foundry. Others come with a view to becoming consulting engineers, or Government engineers abroad, on railways, or on harbour works, or municipal engineers, etc. So that the course mapped out for future life must often determine the preference for certain shops, and of course too, for certain kinds of factories.

But where there are no definite prospects, as must often be the case, the leading departments selected should be those stated just now, with the foundry, dirty though it is, included; and the other departments must be visited frequently. Periods ranging from six months to twelve months should be occupied in the pattern shop and foundry, and in the machine shops and turnery, and the erecting shops, and not less than a twelvemonth in the drawing office. If more time is spent in some, less can be occupied in the others. The shops are generally taken in the order just given. Frequently, however, the time in the drawing office is divided, a portion being taken at an early stage, and the remainder at the completion of the pupil's course.

When in the shops, youths must do just as the apprentices and workmen do. They construct plain patterns, mould plain castings, operate lathes, drilling, or other machines, assist the fitters and erectors in putting machines together, work indoors or out, as required. They are sometimes sent as representatives of the firm on outdoor erections, taking charge of men's time, and the correspondence with the firm in connection with the job of which they have charge. They don the overalls when at work, and have to obey the foremen's or manager's orders, and are, while in the shops, indistinguishable in appearance from the rank and file.

How much time is occupied in any department matters less than the way in which it is utilised. Concentrated effort is necessary if the comparatively short time spent in a shop is to be productive of more than superficial results. All the hours possible in the shop should be "put in," instead of abusing the privilege of a pupil's freedom from absolutely fixed hours.

Here, on the other hand, some conscientious lads fall into error. They stick so closely at bench, lathe, or vice as though the ideal of the apprentice—good craftsmanship—were theirs also. Some few pupils do become really good workmen in one department or more, but that should not be quite the ideal sought. It is very desirable to become adept in the mastery of tools and materials, but it is not altogether in that way that future success will lie. What the pupil should endeavour to attain is a good broad grasp of that which constitutes the work of each department. He wants to learn the practice of each one, only so far as it will enable him to conduct a works with success, either in the capacity of manager or employer.

If, however, his future sphere should be in the department of design, then it is necessary to gather all knowledge that bears directly on that, rather than attempt to acquire high skill in handicraft. Much of this knowledge must be gathered in the shops, equally with the drawing offices, since the production of what are termed workable, or practical designs must be aimed at. Scarcely any man whose training has immured him wholly in the drawing office is able to produce designs that are workable and economical. Many reasons exist for this, but we must pass them over merely with these explanatory remarks:—The cost of labour, the capacities of machines, and the vagaries of many different materials, each enters most vitally into engineering design; and, therefore, in order to design, a man must be thoroughly at home in all of these. But, as this kind of knowledge can only be gathered in the shops, the successful and safe designer must have a good acquaintance with shop practice.

The early stages of shop experience are to

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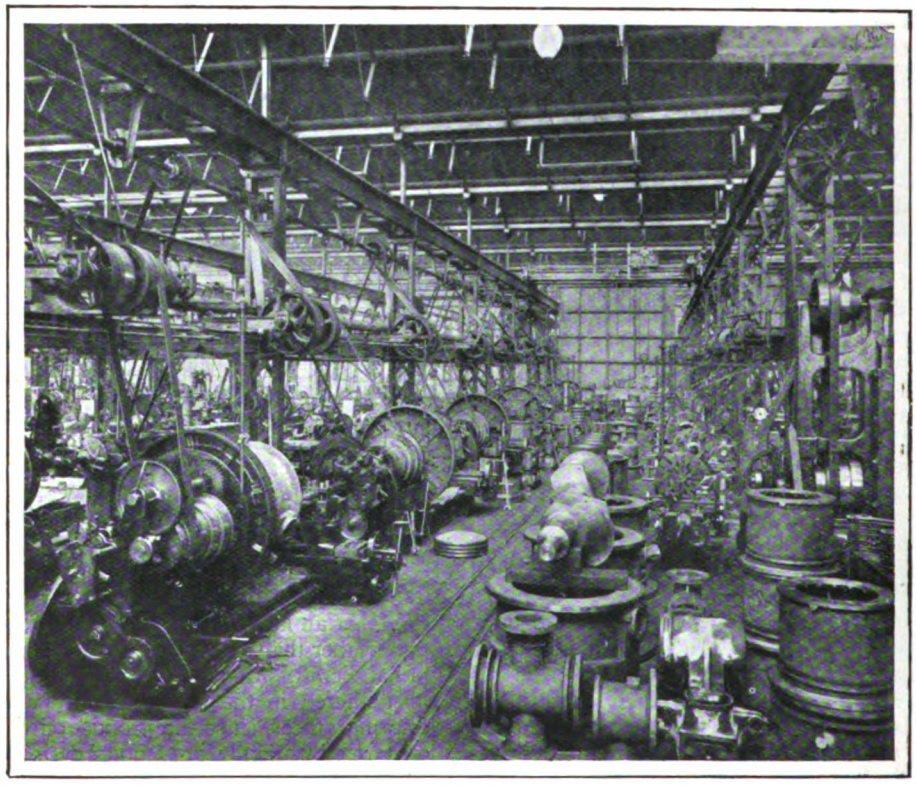
many earnest pupils rather depressing. This is due to the variety and extent of knowledge which has to be assimilated there. The beginner finds that from half-a-dozen to a dozen distinct trades are included in the works, and that important sub-departments exist in several of these; also, that the trades appear to possess little in common, so diverse are the materials and tools employed in them. One thus gets bewildered in the search for a master key or connecting link to the whole. What more diverse, for example, than the wood-working operations performed in the pattern shop and carpenter's shop, and the work of the foundry? In the latter, moulding sand and molten metal are the principal materials employed. Though the smithy and boiler shop again have many points in common, yet they are quite distinct trades, and the machinery and processes of the latter are represented but slightly in the former. The work of the great groups of machine tools, which in many firms forms the largest and most important section of the factory, appears to have scarcely anything in common with pattern work, or moulding, or with forging. The drawing office again seems to stand apart from all the shops. No marvel, therefore, that the lad coming fresh from school into this bewildering congeries of separate shops, sometimes finds his heart sink within him at the thought of how much has to be learned in so short a period.

And yet, after a while, the knowledge which comes with closer acquaintance of the mutual interdependence of the departments yields experiences of another kind. Though each shop includes a separate craft, with its own apprentices and workmen, tools and machines, yet in the aggregate they build up the great industrial organization of the works. The big factory is no longer seen superficially as a disassociated congeries of separate shops, but as an organised body, the elementary portions of which, though independent in action, are yet essential to the vitality of the whole.



TURNING SHOP OF WILLANS & ROBINSON LTD., RUGBY.
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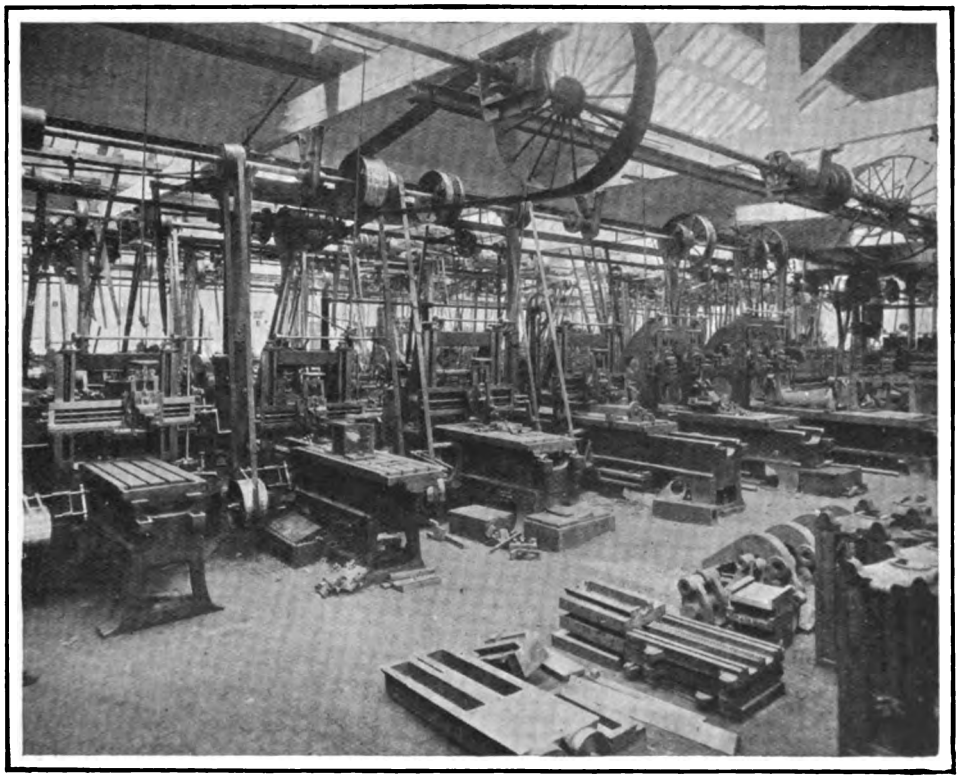
Thus, the analogy between pattern-making, and carpentry and wood-turner's work, is seen to be but superficial, while the relation of that department to the foundry begins to become fascinating. A hundred things that have no connection with the mere art of wood-working are seen to connect the two departments. Taper cores, and core prints in their protean forms, loose pieces, shrinkage allowances, and much besides, have to be grasped, and pattern-making must thus be regarded from the moulder's standpoint.



PLANING MACHINES IN THE WORKSHOP OF C. REDMAN & SONS, HALIFAX.
From a photograph, by permission.

And then, following the castings to their destinations, other connections are seen. The machinist and turner detect scabs, blow-holes, sponginess, minute cracks, harder or softer metals and alloys, insufficient or excessive allowances for tooling, and the moulder is then called to account to explain some of these, and the pattern-maker some others. The smith, the boilermaker, the plater are called into judgment when their work goes to the machinist or the erector, or when inspection and tests take place. Hidden faults, weak sections, inaccurate dimensions, and mistakes must be explained, and similar ones must be avoided in the future. The sins of one department are exposed in another. Even the sanctity of the drawing office is invaded, for the draughtsman's errors are frequently discovered by the workmen and foremen. The latter, too, will often be glad to accept useful hints from the hands. Thus no shop stands alone in the great scheme of the works; and, therefore, the operations carried on in each become in time rendered luminous by the light thrown upon them in the course of the work of other shops.

Another frequent cause of depression to the young pupil is this:—The daintily brought-up lad often shrinks from close association with the workmen. Though this is a foolish feeling, it is nevertheless common, and must be overcome. If a lad is not prepared to rough it along with the hands during the period of his pupilage, he had better seek some calling other than engineering. Actually, the men are mostly good

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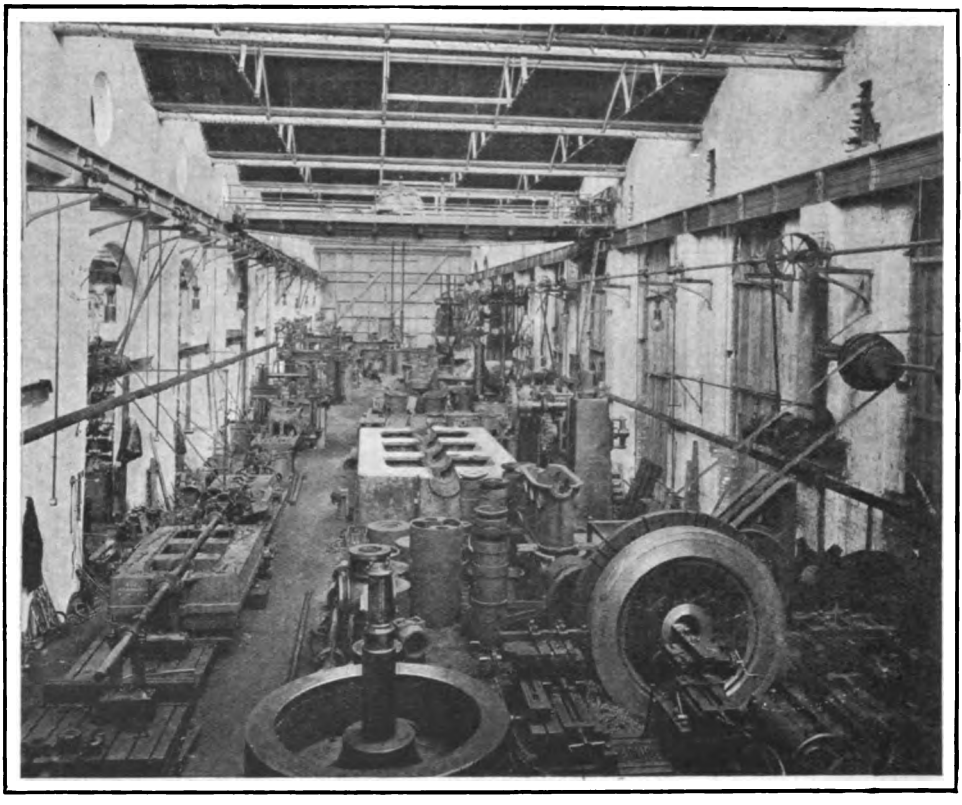
fellows to those who do not put on "side," and they are generally ready and pleased to tell all they know. Willingness on the part of the pupil to lend a hand, and cordiality of behaviour, and good manners, destitute of a trace of patronage, and no telling tales out of school, are the surest way to a workman's goodwill. The workmen, moreover, are not cads, nor steeped in vulgarity, nor lacking in natural courtesy, as many suppose. The presence of a cleanly-minded "gentleman apprentice" has an influence like that of a lady in tending to check observations that might give offence or pain. Many warm friendships develop by virtue of mutual appreciation and helpfulness, and when an old pupil, in after years, pays a visit to his youthful sphere of training, there is mutual pleasure in the recognition of old faces, and talks about the old times.

Another thing which most pupils have strong dislike to is commencing work with the men at six o'clock. They prefer to come down with the office staff at nine. The writer, who knows well what the continuous six o'clock start means, is much in sympathy with this feeling. There is simply no comparison between coming down at six occasionally, and doing the same thing year in, year out. Many workmen go home and get to bed early, and so by securing a good night's rest start fresh in the early morning. But the pupil is expected to go home to study, and, indeed, he must do so if sound theory is to be brought to bear on the practice of the day. To burn the candle thus at both ends requires a strong constitution and as strong a will. For this reason I am of the opinion that the choice of the early start, alternatively with that at nine, should be left to the decision of the pupil and his parents. Years ago, a pupil who started at six was regarded with astonishment; but for some time past the practice of some firms has been to insist on the early start, or at least, to bring strong pressure to bear upon pupils to induce them to adopt it.



FITTING SHOP, WILLANS AND ROBINSON, LTD., RUGBY.
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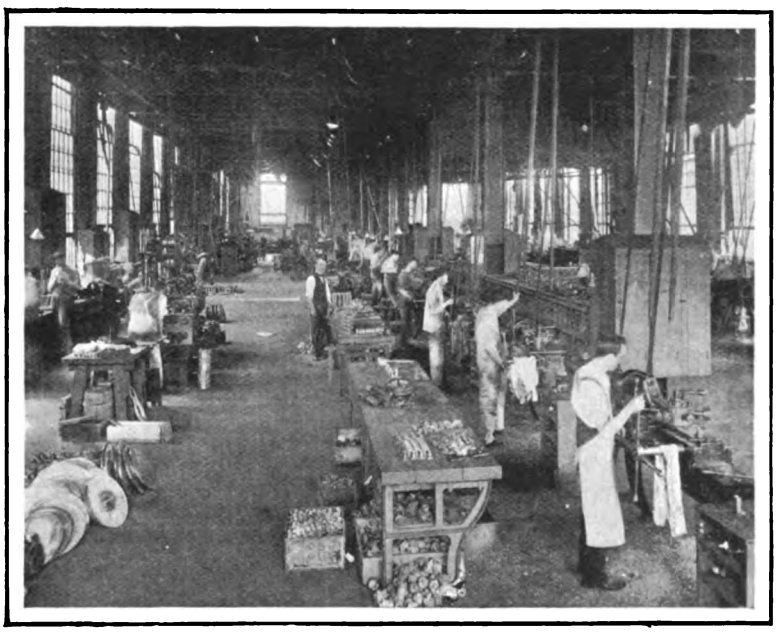
There is no doubt that if a youth is prepared to scorn delights and live laborious days, the two and a half hours before breakfast can be made exceedingly profitable. Generally speaking, work proceeds rather more leisurely before breakfast than after, due to several causes, and there is no interference with peripatetic observing pupils, provided they do not hinder the workmen. On the other hand, if early rising means the sacrifice of evening study, then it is gained at too great a cost, for incessant study is absolutely necessary to supplement the workshop training.

With respect to the course of reading and study which should be taken up, one can only say that it must include all those natural sciences which have applications in engineering practice. These form an immense group. Another of equal importance comprises those works which are commonly termed "practical," because they deal with the various operations that are carried on in the different shops, being written from the craftsman's point of view. Every great department, and many sub-departments of engineering, form the subjects of valuable treatises, low and high-priced, to suit all pockets, and mostly written by men who have worked in these departments for their living. It is not necessary to occupy space in giving lists of these; they may be found in the catalogues of technical publishers. Both of these great groups, the scientific and the practical, number many hundreds of sound standard books, with many of which a young engineer must become familiar if he is to get, or keep, abreast of the accumulated knowledge of the time, and the most advanced practice.

But the best books do not for any long period adequately mirror the advances of the time, apart from the issue of new and revised editions. Hence the cause of the immense value of the technical press, which chronicles week by week, or month by month, the progress of engineering. The pupil must read regularly at least half-a-dozen of these technical newspapers and magazines, but there are quite a dozen which are of nearly equal value in their various spheres, with which he ought to be familiar. No books can take the place of these journals, but each occupies a sphere of its own.

We cannot write of the subject of home study without also offering a few remarks on the relation between the works and the technical schools and colleges. This is, however, a subject too wide to be treated at length in an article dealing with the shops.



Brass-Finishing Shop of the Baldwin Locomotive Works, Philadelphia.
From a photograph, by permission.

There is no unanimity of opinion, even among those who know the subject well, as to the best relations of shop and school. The practical men, and the college men, are both biassed in favour of the grooves in which they have been trained. It is extremely rare to find men who combine the two branches of knowledge in well-balanced relations and proportions. The remarks of the writer, therefore, must be taken as simply expressing his own opinions, given, however, with a full

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knowledge of workshop conditions, and of the needs of pupils.

The so-called "sandwich system," variously modified, is that which seems to meet the case most efficiently. Since the training of the schools has for its ultimate object increased industrial efficiency, it is clear that the student should receive his principal bias, or "permanent set" in the shops, rather than in the schools. Also, he should not be out of touch with the shops for any considerable length of time. A youth ought to make his first acquaintance with the works by about 16 or 17 years of age, and he should then spend, say, a couple of years there—long enough to become familiar with the processes of manufacture. After that, college and shop terms may alternate in periods of six months or so in each, or such other periods as can be best decided by local conditions.

A matter of much importance is the choice of works into which to seek admission. Here, again, one can only deal with generalities, since many matters help to decide the selection. It must be remembered that engineering now comprises many distinct branches, every one of which demands special training. If a lad, or his parents, have no precise idea as to the career of the future, then a shop dealing with general manufactures must be sought, and preferably one of old-fashioned type, where the methods of handicraft still predominate. But if family influence, or strong predilections, map out a definite career, then a shop should be sought of a more special character, one which is more or less engaged in the work which it is the pupil's intention to follow. I say "more or less" because it is not judicious to narrow early training over much. The aim should rather be to build a later superstructure of specialisation on an earlier broad basis of general knowledge. From this point of view, too, it is well sometimes to divide the period of pupilage between two or three works, or to enter pupilage for a short period only, and gain experience afterwards in other works, in subordinate positions.

The mere predilections of a pupil at the commencement of his career hardly count for much. Some youths think they would like to be locomotive superintendents, others desire to get good colonial appointments, other the management of large works, and so on. But such vapourings should be distrusted. The advice of an old engineer is the safest to take. That would be, to gain an elementary and general knowledge of what engineering means before beginning to specialize in one department of practice. The man who has laid a broad foundation can easily drift into specialization, but one who has been trained in a narrow sphere finds immense difficulty in broadening out in later years.

The cost of the training and maintenance of a pupil for a period, say, of five years can hardly be set down at less than £1,000, and it may be considerably more. At the minimum estimate of £50 a year premium, £250 is absorbed at once, and this would have to be doubled in some firms. Maintenance in lodgings would require from £75 to £100 a year, but if a youth lives at home this outlay would be intangible. Then there are books, fees for college terms, drawing instruments, personal expenses, clothes, holidays, etc. Thus £1,000 is obviously estimated on an economical basis. And it must be remembered, too, that the pupil earns nothing during that period: neither is he likely to earn much for three or four years subsequently. By that time his prospects should be assured. He will have made influential friends, as well as gathered experience, and will be prepared to map out roughly his probable life career. But if he is a failure at that period, the chances are that he will be so to the end of the chapter. There are many avenues open to the smart man, for although engineering, like other businesses and professions, is crowded, there is always room near the top.

Though I have emphasized the need of strenuous effort, I must not be accused of painting a heavy, repellant picture. Hard work is quite consistent with much enjoyment, and engineering, to those who love it, is one of the most fascinating occupations the world offers. The hardest-worked pupils have been those who look back to pupilage as the jolliest period of their lives. This fascination is felt alike by the old and young. The great engineers never grow old; the names of many might be called to mind—octogenarians, full of go as ever, loving their occupations as if they were hobbies. The field is so wide, the studies are so many-sided, the progress is so rapid, that every year—nay, every week—brings something new to the engineer. Quoting the words of Longfellow to the naturalist Agassiz, substituting engineering for Nature:—

> "And whenever the way seemed long,
> Or his heart began to fail,
> She would sing a more wonderful song
> And tell a more marvellous tale."

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ON THE DIAGRAMMATIC ILLUSTRATION OF CLASS LECTURES.

A Paper for all kinds of Teachers.

PART II.—THE LARGE PAPER DIAGRAM.

By WILFRID J. LINEHAM, M.I.C.E., M.I.M.E., M.I.E.E., Head of Engineering Dept., Goldsmiths' Institute.

THE MAKING OF THE DIAGRAM.

I HAVE already spoken of the great advantage that paper diagrams have over all the other kinds of illustration in their "staying" quality. Their disadvantage, that of cumbersomeness, must be met by simplifying the methods of their hanging and storage. We have now, therefore, to consider the making, hanging, and storing of paper diagrams. The last two considerations will compel us to decide upon one standard size of paper, for various-sized diagrams are both difficult to store and difficult to hang, and here we must fix upon the size of class or audience that the diagrams are expected to serve. For large popular lectures, or to illustrate papers read before large audiences, the diagrams should be very big indeed, but such sizes are much too unwieldy for class use. It is half a day's work to hang them, and the same time is required for their removal, an amount of time that could not possibly be spared for every-day class work. Turning to the standard sizes of paper, both "Imperial" and "Double Elephant" are too small for classes of more than twenty, and where the students are fairly near the lecturer; but "Antiquarian," which is 53 ins. by 31 ins., I have found quite suitable for classes numbering as many as one hundred students, if the latter are sitting pretty close together. This is the largest of the stock sizes of paper, and about as big as can be manipulated with ease by one person; but if a larger size be deemed advisable, I would allow 60 ins. by 40 ins., but not more. As a matter of fact, it is not necessary to choose the exact "Antiquarian" as the size, because only expensive hand-made Whatman paper can be thus obtained, and one is therefore obliged, for cheapness, to use machine-made cartridge put up in continuous rolls. Such rolls can be obtained 60 ins. wide, and it is best to get them cut up beforehand by the paper merchants. Messrs. Hudson and Kearns stock a very suitable paper, which they are so good as to cut up for me without extra charge into sheets 53 ins. by 30 ins., the price then coming out, I believe, at about 7*d.* per sheet. The same paper would, of course, easily cut into 60 ins. by 40 ins. Although, in my opinion, a fixed size for all diagrams is a necessity, there are some drawings that will not bear reduction to the dimensions of a single sheet, and then the obvious course is to use several sheets side by side, or one large sheet so folded as to retain the standard size.

The paper being provided, it must be pinned to some kind of rigid board, so as to have the diagram drawn upon it. A "drawing" board of suitable size is probably the most convenient, on account of the ease with which a T-square may be applied to it, and such a board had best be made by a local carpenter: it should be grooved at the back, and stiffened with battens that will permit expansion, but otherwise of cheap construction. The T-square, also, need only be of cheap pear-tree wood. The problem now before us is how to most quickly enlarge a small sketch or book diagram to the size of one large sheet; and, do what we will, it is difficult to reduce the labour at this point beyond a certain minimum. Perhaps the most economical way is to depute the work to juniors, for boys can well be trained to such mechanical enlargement, the finishing being

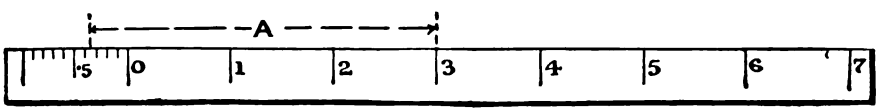

FIG. 1.—SHOWING CORRECT METHOD OF MARKING A SCALE.

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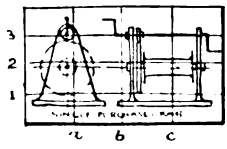
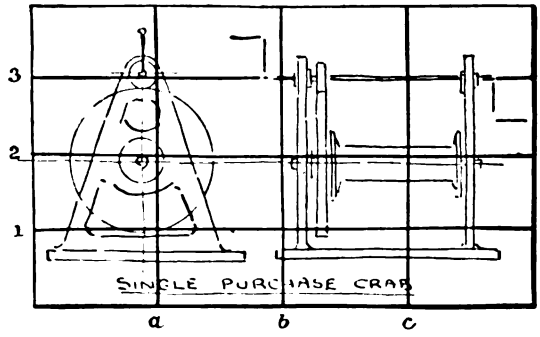
left for more artistic hands. The methods of practically enlarging drawings are (1) by the use of proportional squares, (2) by means of two scales, (3) by proportional compasses, (4) by the pantograph, and (5) by the aid of photography and lantern projection. I think for a practised draughtsman the use of two scales is the quickest method, if a careful reproduction is required, the smaller scale being applied to the little sketch, and the larger one to the diagram paper; but one must of course be ready to make a few paper scales by copying suitable divisions from a 2-ft. rule. I trust I may be forgiven if I refer the reader to Fig. 1, which shows the only proper way of figuring such a scale. You may call the divisions what you please, but they should always be numbered as there shown, and will then be read as divisions and decimals of a division. Thus the length A indicates 3·35 divisions, and if we read 3·35 on the small scale the same dimensions will be transferred by the large scale to the diagram paper. It is only necessary to make a few such large scales, the small ones being purchasable.



The small sketch.



The large diagram.

FIG. 2.—ENLARGEMENT BY PROPORTIONAL SQUARES.

Proportional compasses and pantographs

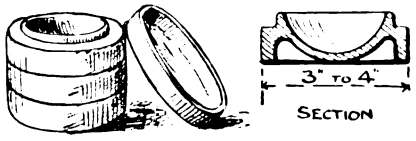


FIG. 3.—NEST OF PALETTES OR SAUCERS.

may be dismissed at once, for they are quite unsuitable for enlargements so great as we are speaking of. I find my compasses will only enlarge to eight times, the largest opening at the small end being then 1 in., and at the larger end 8 ins. Of course larger compasses could be made, but they would be both expensive and cumbersome. The pantograph is also very unwieldy, loose, and springy, and is a terrible bother to adjust, while having the same fault of small enlargement already mentioned. The use of proportional squares is a most important and time-honoured method, dating as it does right back to the old Egyptian dynasties, for proof of which I may refer to some drawings at the British Museum that have had their squares left upon them by the Egyptian artist. It is a method that, for simplicity, runs the scale process very close—in fact, I often use it in preference—and is well-known to scholars as "map drawing." Fig. 2 shows the small sketch and the large diagram side by side, each ruled with the same divisions, the sides of the papers being in this case divided into fours. Points are taken in the large diagram proportionate to those in the sketch, and the whole figure is then drawn in and completed by pencil sketching.

There remains only the method of photographic enlarging, the details of which will be better understood from a succeeding article on the lantern slide. A quarter-plate negative of the small sketch is made in a suitable camera, and this is transferred by contact to a lantern slide. The latter is then projected upon the diagram sheet by means of a magic lantern, the sheet being for the purpose pinned firmly to a vertical board; and while in this condition the operator traces with pencil the lines of the diagram thus projected. The method is thoroughly perfect and satisfactory, but as it involves a good deal of photographic labour, is only to be used in the case of somewhat complicated and therefore deserving pictures.

The diagram having been drawn in pencil, is now to be finished with ink and colour. If the paper be placed on a horizontal board, it is not easy to manipulate, and there is much fear of smudging; so I prefer to pin it to a sliding blackboard, so that it can be raised to any convenient height from time to

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time. Provide yourself with a series of such colours as are required, in water-colour tubes, not cakes or pans, and let the lines be done in ivory black. The brushes are to be of the finest hog's hair procurable, and of various sizes, so as to suit both lines and washes. Circular palettes in nests (Fig. 3), and of good depth, so as to hold plenty of colour, are preferable; a tumbler of water completes the equipment. The black being mixed, the lines are to be drawn by a brush charged therewith, the action known as "lining in" being followed—not the sketching style; and steadiness of line is secured by allowing the third and fourth fingers to rest firmly on the paper. Avoid smudging by drawing a line first in one part and then in another, never passing over the former till it is quite dry. Lining only may be sufficient for the purposes of some diagrams, but it must not be forgotten, that the use of various colours to fill in the spaces, not only enhances the design, but makes it much more clear and apparent to the student. Such washes should be applied carefully, so as not to disturb the black lines, and their character must depend largely on the subject, so it is difficult to describe here what would be done in individual cases without the aid of colour itself; above all, let the colouring be effective and striking, while not too dark.

Lastly, the diagram is to be lettered, for more reasons than one. Such lettering serves as a title, by which the diagram is to be afterwards known, while it is also an incentive to the student's remembrance. Those teachers who are not facile at lettering would do well to use large indiarubber stamps and good black ink; but hand lettering is always more fitting to the diagram, for the letters can be contracted or expanded in width at pleasure. The best for the purpose are known as block letters, thus:

ALLAN'S LINK MOTION.

They are easily learnt by reference to good printers' type, of which I give herewith an alphabet:

A B C D E F G H I J K L M N O P Q R S T
U V W X Y Z & 1 2 3 4 5 6 7 8 9 0.

It is well also to add a letter and number at the right-hand bottom corner, as in Fig. 4, the letter indicating the drawer where the diagram is to be placed, and the number showing its order in the drawer. A list of diagrams as kept in each drawer is placed in any convenient wall position—in, say, the preparation room, and the diagrams wanted for each class are indicated in the lecturer's note book. Once a year, during the summer, all the diagrams in each drawer are classified, commencing from the top and proceeding downward, so that any particular number is easily procured. The discarded diagrams are merely replaced on the top, pending reclassification the succeeding summer. As to the letters for each drawer, I use S for "steam," D for "machine drawing," M for "mechanics," B for "building," A for "architecture," and so on; so that they shall be easily remembered, for the placing of diagrams in wrong drawers is a not uncommon fault. Above all, be sure that the title is put at the *bottom* of the diagram, so that it may be easily read in the drawer without removal.

The diagram made to the instructions thus given is a really satisfactory result, and is well worth the time given to it in the

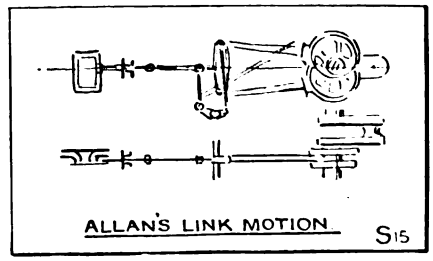

FIG. 4.—LETTERING ON DIAGRAM.

making; but time it does really require, and anyone connected with the working of a busy technical college knows that time is a scarce commodity: in other words, labour-saving should be the order of the day. There is no doubt that the man who can draw freely, proportionately, and accurately, without the aid of squares, and with only the rare assistance of compasses, is capable of making diagrams at an infinitely greater rate than his less skilled brother; and although such faculties do not often occur, yet they should be cultivated as far as possible by all diagram makers. Charcoal, as obtained at the artist-colourman's, is a splendid material for a temporary diagram, but such diagrams can only be used once or twice without smudging beyond recognition. To make the quickest and yet lasting diagram I pin a sheet of paper upon a sliding blackboard, and sketch in the picture lightly and quickly with charcoal. I next go over the charcoal

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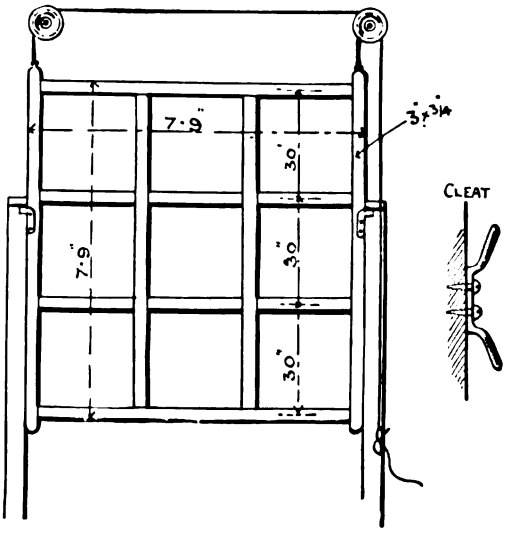
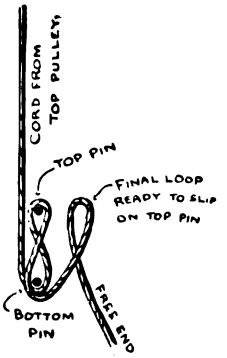
picture with lead pencil, using the latter rather lightly, so as to avoid making a shiny surface, and putting in the large circles with a pair of blackboard compasses. The charcoal may then be dashed off with a handkerchief, leaving the pencil picture. I now procure a set of chalks in various colours, such as are made in thick sticks for writing on parcels, and which may be procured at the stationer's. These are of a greasy composition, so that they do not rub off the diagram with ordinary usage, and when drawing with them they are best set in a large crayon-holder, for they otherwise tend to break in the hand. The pencil diagram is now lined in with black chalk in the same manner as with the colour-brush, and all "washes" are to be given by





The Sailor's Hitch.

FIG. 5.—FRAME OF HANGING DIAGRAMS, WITH DETAILS.

scribbling or hatching with suitable colours of chalk, for water-colour washes do not lie so well in proximity to the greasy chalk. If the lead pencil was used lightly, the result of the chalk line will be a bright and clear diagram almost as good as the water-colour picture previously described, almost as lasting, and very much more quickly made, for there is no waiting for colour to dry. From my own experience I cannot speak too highly of this method, mainly on account of its speed; for I often find myself able to make such diagrams directly with chalk during class time, just as one would draw upon the blackboard; while if one has a teacher gifted in blackboard drawing, it is only necessary to provide him with a "white board" and sufficient chalk to make his diagrams permanent.

THE HANGING OF DIAGRAMS.

There is no doubt that the greatest objection to the use of diagrams is the labour of sorting and hanging them, but all methods have drawbacks of some kind, which it is our business to lessen as much as possible. I have already shown how diagrams may be quickly picked out, if they are given distinguishing numbers and letters, and are arranged in order in their respective drawers. Now as to their hanging, much more space is required as a rule than I showed was wanted for blackboard work, and such space can only be found at some height on the walls. Some kind of wooden frame has therefore to be constructed which can be raised and lowered quickly, so that the diagrams may be pinned upon it; and this frame must be lifted by ropes, as with a sliding blackboard; but as the construction need not be heavy, the balance weights can be dispensed with. The frame must be built with regard to the size of diagram that is to be used upon it, so that the one shown in Fig. 5 would be suitable for sheets 30 inches wide, or "Antiquarian." As mentioned, it is supported by cords passing over pulleys above it, so that two such cords pass over one of the pulleys and depend down one side of the frame, where they have to be fastened to a cleat. At a point halfway between the pulley and the cleat, however, the two cords are joined into one by means of a strong splice, and from that point downward only one cord is used, so that there is less trouble in fastening it to the cleat. When the frame is lowered, the diagrams are pinned on with drawing pins, and as a very large number of pins are required for use and for replacement (especially the latter) a cheap and strong form must be obtained. Such, in my opinion, are the all-steel stamped pins which I procure from Messrs. Reeves, Limited, being known as "L 3." The frame being raised to its

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highest position, the rope must be fastened to the cleat by means of a "sailor's hitch," which I have endeavoured to show in the diagram, the rope going round the lower pin first, then by a right-hand turn round the upper pin, and a left-hand turn round the lower pin. Finally a loop is made, passed on to the upper pin, and pulled tight, the free end lying at the back of the loop. I need hardly say that the frame I have described may be either made to slide between guides, or may be allowed to hang freely, for it is much lighter than the blackboard; but guides are preferable, for they give a resistance while pinning, and prevent the flapping about of the frame.

I once had the pleasure of using an exceedingly cheap yet effective method of hanging diagrams, when lecturing at the School of Military Engineering of the Royal Engineers at Chatham—a method also by which an enormous amount of space was made available without seriously or permanently interfering with the wall for other purposes. Horizontal laths of wood, as in Fig. 6, were supported by being hung upon vertical strong tapes, and the frame thus formed was supported by cords over pulleys as I have just described for the rigid frame, so that it could be raised and lowered in a similar manner. I do not say that the arrangement is as pleasant to pin diagrams upon, but it is certainly cheap, and it has decided advantages over the rigid frames. For when the apparatus is not required it can be lowered to the ground, the laths fastened together with a strap of leather, and the compact bundle thus formed can be raised to the ceiling, leaving the wall free for other purposes. Also a portion only of the frame may be treated in like manner: in other words, the system is elastic.

There are some diagrams which it is desirable that the student should see constantly from one year's end to the other, while the majority of diagrams are of course only pinned up for the particular class. I thus distinguish between "permanent" and "temporary" diagrams. To mount the former I have recourse to a contrivance described in my last article as a "wood book," only that instead of the leaves being made into a series of blackboards, they only consist of light wood frames, stayed at the corners as I have shown in Fig. 7. The diagram itself, being for hard use, must be made on Whatman continuous paper backed with holland. After making, it should be moistened a little at the back, and then nailed to the frame by tacks an inch apart, and it will, when dry, become taut and level, and may then be bound round the edge with strong paper or cotton. The surface must next be coated with a size of isinglass or of Russian glue dissolved in hot water, as a preparation for the varnish. Much care is to be exercised in putting on the size, or the colours will be washed up, and it is therefore better to go over the surface very lightly with a thin coat by means of a soft brush, and after that becomes dry a stronger coat is easily laid. The varnish should be the most transparent procurable: that known as mastic varnish is undoubtedly the best, although somewhat expensive.

I have recently taken advantage of the

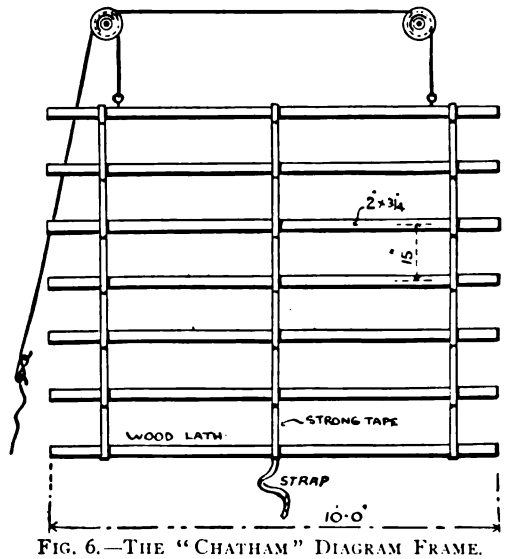

FIG. 6.—THE "CHATHAM" DIAGRAM FRAME.

rigidity of the wood-book system to apply thereto some diagrams having moving parts, such as pistons in cylinders, valve motion, etc. For this purpose I have used "compoboard," which is made up of wood covered with strawboard, and is only then about $\frac{5}{16}$ in. thick. This I have fitted to the open space in the leaves, allowing the board to rest on the corner stays and be fastened there. The moving parts are of stiff paper stuck to thin, flat brass laths, which slide by slots upon wood screws.

THE STORAGE OF DIAGRAMS.

There appears to be no satisfactory way of storing diagrams but to lay them in drawers, for they are always too large to treat as books are treated, in a vertical fashion. No

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doubt the method is responsible for a great deal of the damage that is suffered by diagrams, but although good drawing offices have been in use for a hundred years, no scheme other than that of drawers has yet been discovered for mechanical drawings. The drawer being a necessary evil, its defects must be minimised, and there must never be too great a depth, or the weight of drawings will tear the one we may be removing from the bottom of the pile. A fair depth is about $3\frac{1}{2}$ inches: more than this is doubtful policy; and the length and width of the drawer inside should exceed the diagrams by an inch each way. To prevent the diagrams curling up at the back edge, a board must be nailed over the drawer, which should reach forward quite 12 inches, or its object will be still defeated, a narrow board being found quite useless. A number of these drawers having been enclosed within a suitable case or chest, the problem of where to place the latter still remains, for in no class-room have we much floor space to spare. I have solved the problem to my own satisfaction by placing the drawers under the lecture table of the class-room where the diagrams are most wanted, and the arrangement has proved compact and handy. The diagrams may be picked out during a lecture if any have been forgotten, and the only objection that occurs is that many class-rooms are too small to admit lecture tables. In such cases they must, of course, be stored in rooms that have the space. The table becomes certainly a little wider than is absolutely necessary for lecture work, but not unduly so. Sliding doors are always troublesome in actual practice, and should not be adopted except in extreme cases. I prefer therefore to apply the usual hinged doors, in which case there must be sufficient space left for a passage when the doors are open, as I have indicated in Fig. 8, which sufficiently illustrates all that I have said on the diagram cupboard.

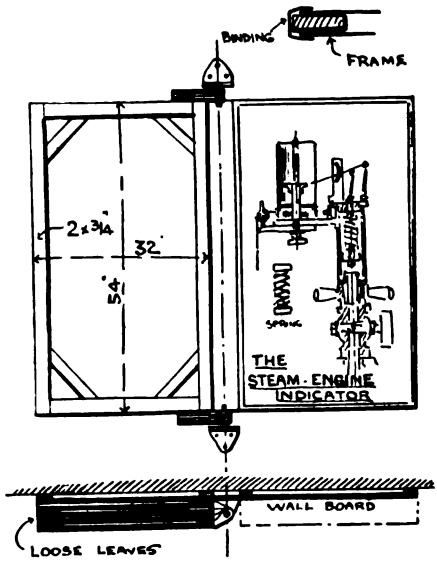

FIG. 7.—WOOD BOOK FOR DIAGRAMS

When the diagrams are re-sorted in the summer they should be entirely removed, arranged, and returned in one batch per drawer. I mention this because some attempt to slip diagrams one under the other, to their considerable damage. Of course diagrams are sometimes torn, even though the greatest care be exercised, and as the "stitch in time" applies in their case most particularly, I make it a rule that the annual patching should take place simultaneously with the re-sorting. With such precautions as I have mentioned, diagrams may certainly be made to last the proverbial lifetime, some in my own possession being quite twenty-five years old.

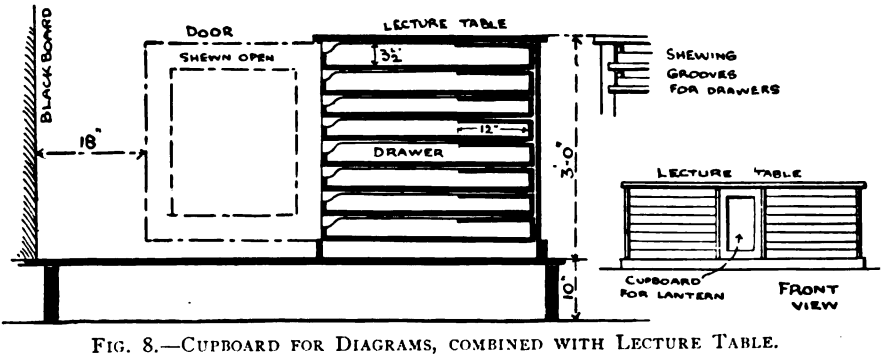

FIG. 8.—CUPBOARD FOR DIAGRAMS, COMBINED WITH LECTURE TABLE.

(*To be continued.*)

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"CHARLOTTENBURG," THE BERLIN TECHNICAL HIGH SCHOOL.

PART II.

By Professor W. E. DALBY, M.A., M. Inst. C.E.

IT was stated in the first article that the instruction given at Charlottenburg is of university rank. Let us examine this a little more closely. Consider the course of study arranged in the department of architecture. There are about eighty separate courses of lectures and exercise classes from which a student may make his selection, the subjects ranging from those of a purely technical character, like the "Strength of Materials," to those of a more academic character, like the "History of Roman Architecture," and including lectures on the fine arts. Besides the subjects dealt with in this department, the students are recommended to take lecture courses belonging to other departments where these courses have a bearing on particular branches of architecture. A glance through the following list of lecture subjects will indicate the wide and comprehensive character of the instruction provided in this department.

FIRST YEAR.

Practical geometry.
Experimental physics.
Experimental chemistry.
Surveying.
Building construction.
Drawing, including figure and landscape drawing.
History of architecture: the antique.
Modelling: figure and ornament.

SECOND YEAR.

Mineralogy, geology.
Building construction: higher course.
Principles of design: railways, roads, waterworks.
Strength of materials.
History of Greek and Roman architecture.
Furniture: antique, Renaissance, 18th century.
Drawing: plans, figures, etc.
Estimates and specifications.

THIRD YEAR

Sanitary engineering.
Iron buildings.
Design of buildings in stone, brick, and wood.
Design of public buildings.
Gothic buildings.
Architectural perspective.
Heating and ventilation.
Figure design from living models.
Modelling.

FOURTH YEAR.

Machine construction.
Colour decoration.
Lectures on the history of Greek, Roman, Renaissance, and Gothic architecture.
The design of buildings in various styles and in various materials.

It must not be supposed that a student entering the school to study architecture is compelled to take the course laid down in the syllabus. The published detailed plan of lectures and exercise classes in the department is only a recommendation by the authorities of a suitable sequence of work. Students are free to select and attend lectures in any order they choose, and they would resent any attempt on the part of the authorities to make any specified course of study obligatory as an infringement of their right of "academic freedom," a right guarded by the students throughout the universities and technical schools of Germany with great jealousy.

The following notice, which is placed at the beginning of the division of the syllabus which gives the plans of study recommended by each department, shows well how careful the authorities are not to do anything which appears even to interfere with the students' freedom:—

"The following plans of study have not been arranged with the object of diminishing the students' freedom of selection. On the contrary, they are designed to assist students in making their choice, and for this purpose the lectures have been arranged in the order

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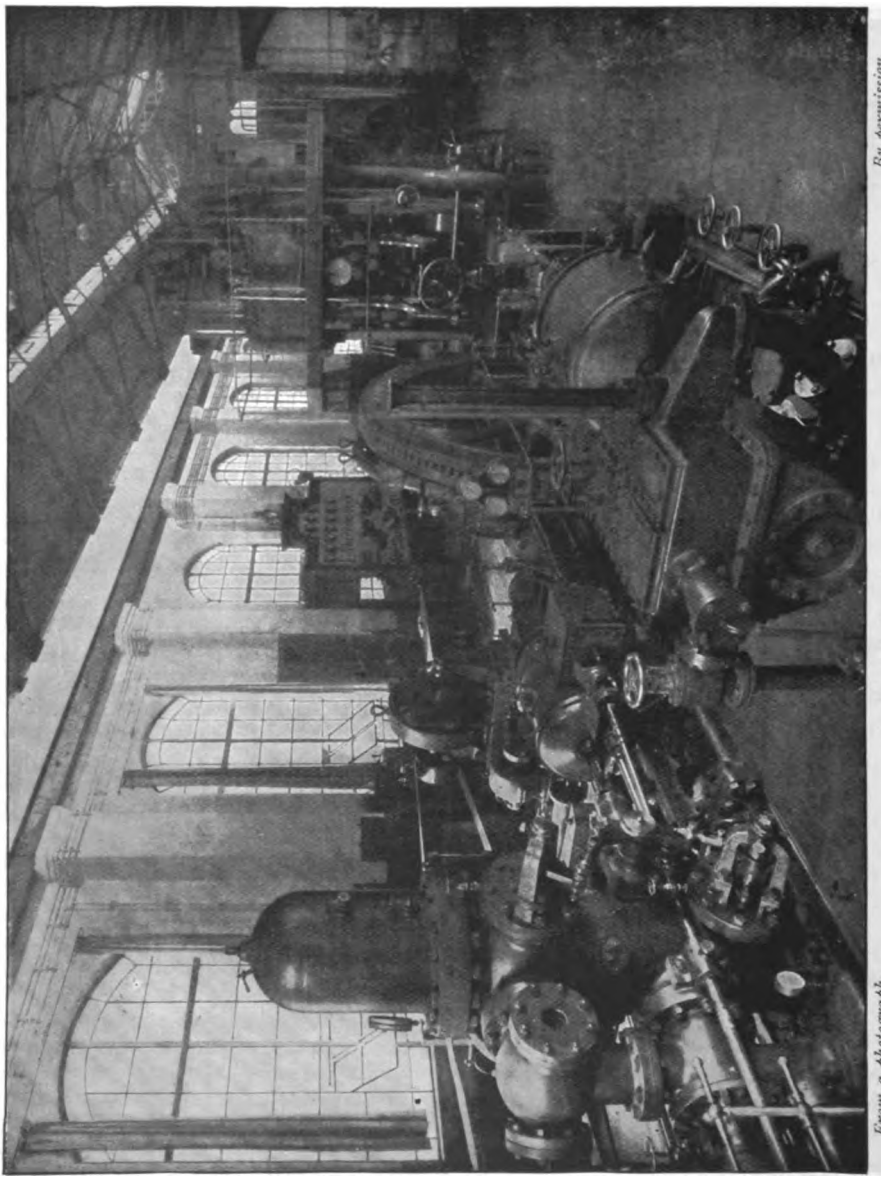
in which they can appropriately be taken. Students are recommended not to take up too many courses, involving more work than they can properly do. The advice of the head of the department may be taken with respect to the choice of lectures. Students to select any course of study he thinks fit, made up of lectures from any of the six departments of the school.

Over 40 per cent. of the students at the school are to be found in the department of mechanical engineering, about one-fifth of



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STEAM-ENGINE LABORATORY.

From a photograph.

of the first and second half-year are required to enter in a form the lectures they have selected, and their selection must be confirmed in a personal interview with the head of the department of general studies."

A student, therefore, has perfect freedom these specialising in electrical engineering. The course offered may therefore be examined in detail. The first feature to be noticed is that there is no attempt to teach workshop practice. What workshops there are in connection with the school exist

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merely for the purpose of making and maintaining apparatus. It is quite the opposite in the American universities and technical schools. There, workshops are either attached to the school, as at Cornell; or use may be made of the workshops belonging to adjacent schools of manual training, as at Harvard. But, in any case, a training in workshop processes—turning, fitting, forging, pattern-making, and the like—forms an integral part of the training of a student taking the mechanical engineering course at an American technical institution. In our own institutions there is no definite agreement about the matter. Workshops exist in many cases, but the work done in them is inconsiderable, and the trend of opinion is that the practical training of the student should be obtained in an engineering establishment, working with the men under the same conditions of hours and service, in order to obtain a knowledge of workshop management as well as the manual skill in workshop processes.

Laboratory work in connection with engine testing is, however, amply provided for at Charlottenburg. A laboratory about 200 feet long and 40 feet wide has been erected in the grounds, away from the main building of the school, and connected therewith is sufficient boiler plant to supply the steam required. An illustration of the interior of this laboratory is shown on page 144. On entering the laboratory, one is impressed by the quantity of apparatus crowded into it. Here is a triple-expansion engine by Goerlitz, fitted with Cullmann expansion and cut-off gear, and developing about 150 indicated horse-power. Working in combination with this is an experimental plant, the purpose of which is to study the economy obtainable when the heat of the exhaust steam from the engine is transferred to another fluid (sulphur di-oxide in this case), with the object of rejecting the heat finally at a lower temperature than is possible when using steam alone. Close to this is a vertical engine of about 150 horse-power, fitted with the Marshall valve gear, and loaded with a dynamo. Near this, again, is a horizontal engine of about 150 horse-power, loaded with a set of Riedler pumps. In another part of the laboratory is a 100 horse-power Diesel motor, on which important researches were made by one of the Charlottenburg students. Here is a hydraulic motor of about 100 horse-power; there is apparatus for experimenting on the flow of steam, and connected with it a 20 horse-power portable engine. There is also an air-compression plant installed, and various small engines and less important pieces of apparatus are distributed through the laboratory where room can be found. At one end of the building there is a 150 horse-power gas-engine driving generators for the purpose of lighting the building. In this one laboratory there is installed apparatus of one kind and another approximately equal to 800 horse-power. Students are recommended to begin work in this laboratory in their second year, and a course occupying four hours per week is arranged for them. The next year's course is arranged for six hours per week, and the last year—that is, the third in the laboratory and their last in the school—extends over ten hours per week. The laboratory is under the direction of Professor Josse. The electrical engineering laboratory (p. 147), under the direction of Professor Slaby, is in the main building of the school, and is formed by roofing in one of the square courts which were shown on the plan illustrating the article in the January issue.

Probably the most striking feature of the course is the large amount of time devoted to exercise work in the drawing offices. There are a large number of rooms in the main building used for this purpose, and a recently erected wing added to provide increased accommodation for the engineering department consists mainly of a succession of drawing offices. Incidentally, the kind of drawing-board used in this department may be mentioned; namely, a large board supported on an easel, the T square being flexibly connected to the drawing-board and sliding over the surface, perfectly under the control of the draughtsman. The method of instruction in this department is noteworthy. Professor Riedler, who directs the department of machine design and allied subjects, carries on a large private practice in the building, employing between twenty and thirty draughtsmen for the purpose. The majority of these men take part in the teaching given in the drawing offices, so that mechanical drawing and machine design are taught by men engaged continuously in actual designing of engines and pumps for installation in various parts of the world. No better method of teaching machine design could be devised, because to all intents and purposes the students are working under actual drawing office conditions. Professor Riedler delivers a series of lectures on machine design, pumps, blowing engines, air compressors, and mechanical drawing generally, whilst the lectures on steam-engine design are given by Professor Stumpf, who is

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associated with Professor Riedler in the direction of the department.

A student at Charlottenburg has not much opportunity, at the present time, of familiarising himself with the properties of materials by means of actual experiments. It is true that the Government testing establishment (Königliche mechanischetechnische Versuchanstalt) standing in the grounds of the school, is associated with the institution; but the pressure of work there is too great to allow any considerable number of students to themselves use the machines. They are allowed to attend the establishment for stated times per week, in order to see experiments carried out. The department is in process of removal to Grosslichtefelde, so that ultimately the buildings will be handed over to the school for a testing laboratory in which the machines are used primarily for purposes of instruction. The well-known Director of the Versuchanstalt, Professor Martens, whose chief work is in connection with the organisation and management of the Government laboratory, is a professor of the High School, and gives regular courses of lectures on the strength of materials.

The plan of study recommended to students in this department is given below. It may be remarked that for the first three years all students are recommended to follow the same course, specialisation being reserved for the fourth year. Then choice may be made of a course in—

(*a*) General mechanical engineering.
(*b*) Railway and locomotive engineering.
(*c*) Electrical engineering.

FIRST YEAR.

Experimental physics.
Higher mathematics.
Mechanics 1.
Descriptive geometry.
Mechanical technology 1.
Introduction to machine construction.
Experimental chemistry.

SECOND YEAR.

Mechanics 2.
Mechanism.
Thermodynamics.
Strength of materials.
Graphic statics.
Cranes and lifting machinery.
Practical work in the engine laboratory.
Mechanical technology 2.
Commercial subjects.

THIRD YEAR.

Electricity.
Crane design.
Steam-Engine construction.
Hydraulic machine.
Practical work in the engine laboratory.
Masonry construction.
Pumping, compressing and blowing machinery.
Steam boilers.
Statics of bridge construction.
Finance and banking.

FOURTH YEAR.

(a) *General Mechanical Engineering.*

Design of hydraulic machines.
Setting out factories for various purposes.
Machine construction.
Hydraulics.
Design of boilers.
Practical work in the engine laboratory.
Ice-making and refrigerating machines.
Practical work in the electrical engineering laboratory.
Construction of dynamos and transformers.

(b) *Railway Engineering.*

Locomotive carriage and wagon construction. Permanent way.
Railway working.
Setting out factories, etc.
Iron construction.
Iron bridge construction.
Electric telegraph.
Practical work in the engine laboratory.
Practical work in the electrical engineering laboratory.
Transport of goods.
Construction of dynamos and transformers.

(c)

Practical work in the engine laboratory.
Construction of dynamos and transformers.
Practical work in the electrical engineering laboratory.
Electrotechnics with relation to the Electric telegraph.
Electric measurements.
Electric lighting.
Alternating currents.
Electric transmission.
Electric railways.
The physical basis of electrotechnics.

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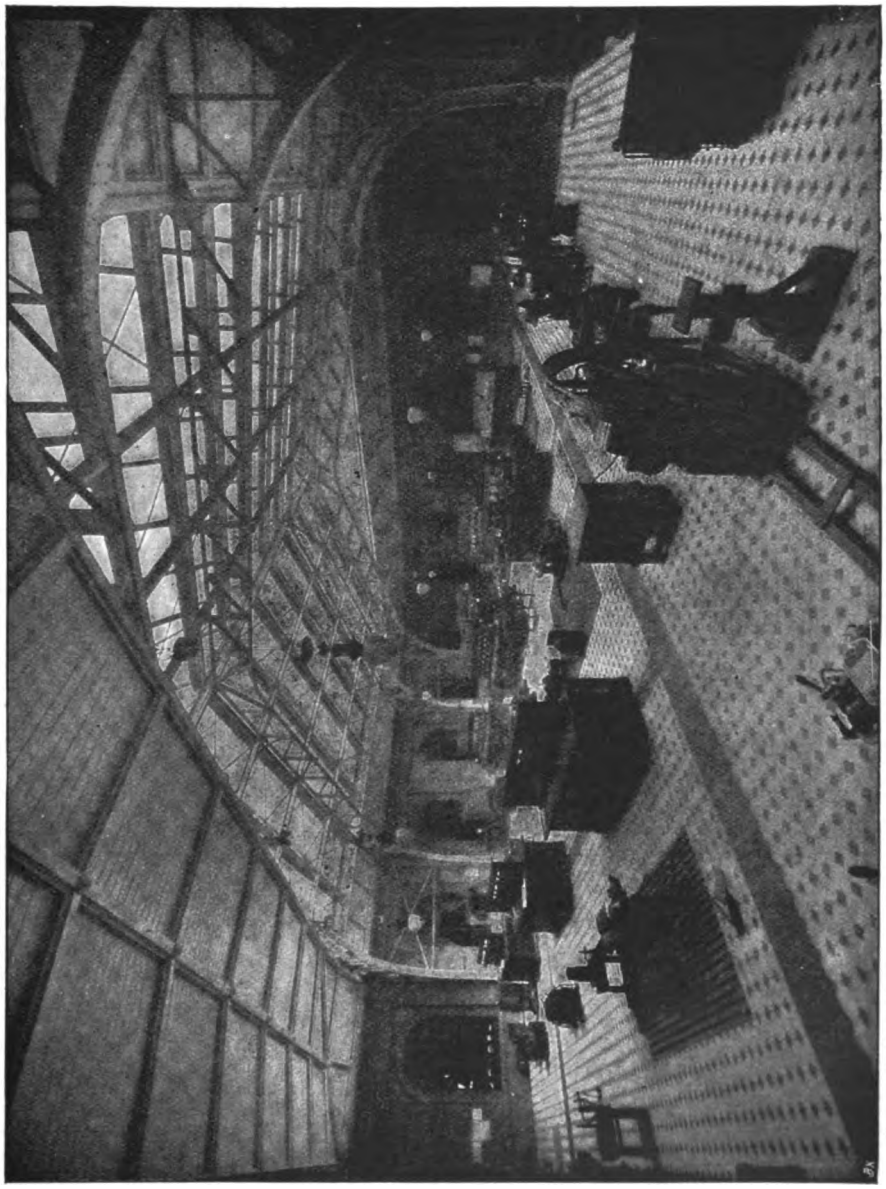
Electro-chemistry.
Introduction to the potential theory.
Potential theory and its employment in the study of electricity.
Electric waves.

(with us the longest is three years); but chiefly because the students come to the school so much better prepared to begin a technical course. They start, in many cases, with a knowledge of mathematics equal to that with



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ELECTRICAL LABORATORY.

From a photograph.

The great difference between the best courses of instruction offered in engineering in this country, and the course indicated above, is that at Charlottenburg the work is carried to a higher degree of specialisation: partly because the course occupies four years, which our students finish their course. It is hopeless to attempt to increase the standard of training in this country until the students come to the colleges in a better state of preparation. Regarding specialisation, no institution in this country offers any special

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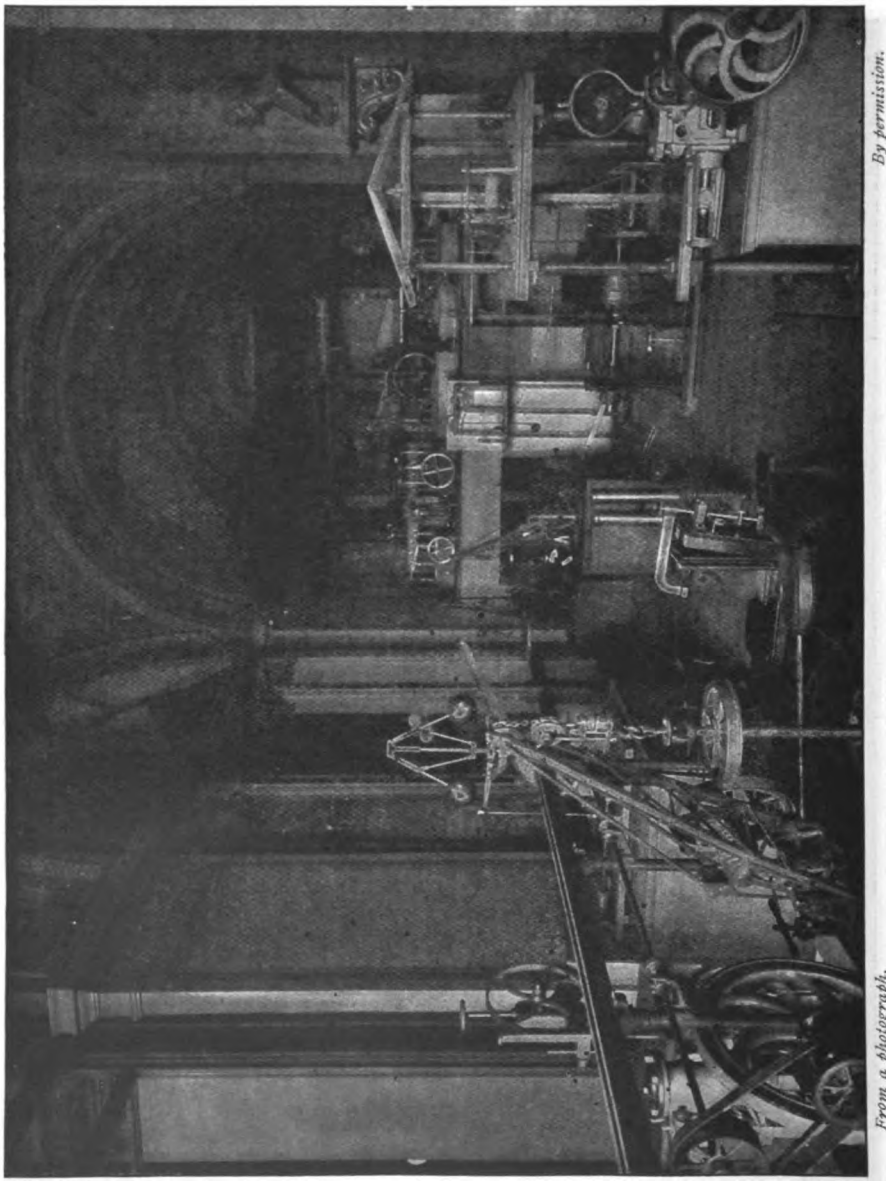
instruction in connection with locomotives. At the Technical High School lectures are given in connection with locomotive work and railway work in general, by Professor von Borries, one of the most eminent locomotive engineers in Germany. The advantage to our railway companies would have been great, if even one course of instruction had existed in this country, where a combined lecture and laboratory course was at the disposal of a man who had served the usual apprenticeship of four to five years in the shops of some locomotive establishment; and if men trained in this way had been regularly absorbed into the locomotive departments of our various great railways.

The detailed examination of these two departments of the school will have shown how thoroughly the instruction is organized at Charlottenburg.

Nothing need be said with regard to the chemical department. Those interested in this branch of the work should consult the pamphlet issued by the Foreign Office, July,



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THE MUSEUM OF ENGINEERING MODELS.

From a photograph.

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1901, entitled "Chemical Instruction and Chemical Industries in Germany." It is No. 561 of the Miscellaneous Series of Diplomatic and Consular Reports. In this publication the chemical courses in all the universities and technical schools are examined and commented upon: statistics are given of the numbers of students passing through them; and an endeavour is made to trace the relation between the German system of technical education in chemistry, and the increase of the chemical industries of the country.

Of the total number of students in the school, in the winter half-year of 1902–1903 (namely, 4378), 3017 were Prussians, 614 came from other parts of the German Empire, 343 were foreigners, and the remainder, 381, were admitted under various special regulations, and included 34 officers of the German Royal Navy taking special courses. Of the foreigners, 84 were Russians, and 85 Austrians, 44 Roumanians, 36 Norwegians, the remainder being distributed between the other European countries, 13 coming from Great Britain.

Students wishing to learn Russian, English, or Italian at the school may do so, because special lectures are arranged for the teaching of these languages.

There are various small museums distributed through the school, each containing collections of models, instruments and objects illustrating various specialised branches of study. There are in all twenty collections of this kind, a list of which is given below:—

1. Beuth-Schinkel museum.
2. Collection of plaster casts.
3. Callenbach collection.
4. Architectural museum.
5. Building materials.
6. Models of buildings.
7. Surveying instruments.
8. Street railways.
9. Hydraulic engineering.
10. Ironwork construction.
11. Railway construction.
12. Collection of iron bridge models.
13. Reuleaux collection of kinematic models.
14. Railway machinery.
15. Mechanical technology.
16. Machine models.
17. Models of ships.
18. Photo-chemical collection.
19. Mineralogical museum.
20. Collection of physical apparatus.

These museums are opened to students at stated times. Probably the most famous of these collections is that of the kinematic models devised by Professor Reuleaux to illustrate his theory of mechanism and machines. Copies of some of these models are to be seen in almost every collection of mechanical apparatus used in the teaching of mechanical engineering, and the Reuleaux system has become incorporated to a greater or less extent in the engineering course of most engineering colleges.

The collection of bridge models is an interesting one: so is the collection of railway machinery models, though it is not kept quite up to date. The museum of machine models is illustrated on page 148.

It may be noted that the Berlin Technical High School has gradually grown from small beginnings to its present proud position as the greatest technical university of the world. Started initially as a polytechnic school about a century ago, it was founded as a technical high school in 1821. In 1870 it was changed into a trade academy (Gewerbeacademie) combined with a building academy (Bauacademie). These were again combined into the Berlin Technical High School in 1884, and the present building erected for the accommodation of 2000 students at Charlottenburg, as stated in the first article.

There is a feature in the organisation of the teaching staff which is worthy of attention. Though one Professor, the Vorsteher, is head of the department, he is not expected to be an expert in every branch of the studies which he directs. Many other professors are associated with him on an equal educational basis, each an expert in a particular branch, and in general engaged in the full practice of his profession. In this way the teaching in every branch is kept constantly in touch with the professional questions arising in practice, and theory and practice are brought together in a close union. Of course the cost of maintaining such an establishment as the Berlin Technical High School is considerable. For instance, in 1899, the total income of the school was nearly £70,000, of which nearly 50 per cent. was provided by the State.

A few particulars in connection with the fees charged and the method of computing them may be of interest. The fee for a particular course of lectures or an exercise course is reckoned for the half-year, and is based on the number of hours per week the lecture or exercise course occupies. A distinction is made between students and hospitanten: the former paying for lectures at the rate of four marks (a mark is equal to about one shilling)

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per hour, reckoned over one week for the half-year: the latter five marks per hour reckoned in the same way. Again, exercise classes are paid for at a lower rate, but still the student has the advantage over the hospitanten, paying on a basis of three marks per hour-week for the half-year, whilst the hospitanten pays four marks.

Suppose, for example, a student selects lectures in the Department of Architecture, which occupy five hours per week, and accompanying exercise classes occupying five hours per week. The fee, payable in advance, would be five hours at four marks per hour, plus five hours at three marks per hour, equal to thirty-five marks for the half-year. That is to say, a student receives ten hours instruction per week for the academical half-year (about four and a half months) for thirty-five shillings.

The corresponding fee exacted from one of the hospitanten class would be forty-five shillings.

The laboratory fees are relatively higher. Thus the inclusive fee for the chemical laboratory is eighty-five marks per half-year. The fee for the heat laboratory is fifteen marks, for the engineering laboratory fifty marks, for the electrotechnics laboratory fifty marks, all for the half-year.

It is stated that a yearly expenditure of from 300 to 350 marks is sufficient to cover the cost of a suitable course of study and laboratory work in any department. The best technical education procurable can therefore be obtained for the modest sum of from £15 to £17 10*s*. per annum.

A further amount of 15 marks caution money is required from students in the chemical laboratories, to pay for possible damage or breakages of the apparatus entrusted to them. In the engineering drawing offices, 2 marks caution money per annum is exacted to pay for the maintenance of the machine models.

This slight sketch of the Berlin Technical High School may be fittingly concluded with the following quotation from the Foreign Office Consular Report above mentioned: —

"His Majesty the Emperor William has always manifested a deep appreciation of the vital importance of technical education, and of the progress of science and chemical and technical industries. He has displayed this in many ways, by participation in scholastic conferences, by the admission of the directors of Prussian technical high schools to the Prussian Upper House, and latterly, by honouring the Prussian technical high schools with the right to confer the new degree of doctor of engineering upon the occasion of the centenary of the Berlin Technical High School. This is a most important historical event in the annals of the development of scientific education in Prussia, as it indicates that the technical high schools have been raised to the academic level of the older universities. This honour, great in itself, was further enhanced through the Emperor by the bestowal of the title of "His Magnificency" upon the professor elected each year to the office of Director of the Berlin Technical High School, and by the additional right of conferring the degree of *Doctor Honoris Causa* upon distinguished scientists, scholars, and public men.

"The importance of the step taken by the German Emperor cannot be too highly estimated. It practically means a recognition and acknowledgment of equality given by the old universities, with their honourable historical records of many centuries, to their younger colleagues, the technical high schools of the nineteenth century.

"Since the elevation of the technical high schools to the same rank as the four faculties of the old universities, German educationalism has now attained a certain measure of perfection in the last of its three great historical periods—the appearance of the universities as a living protest against the dreary and fruitless scholasticism of the middle ages: the foundation of academies with the principle of experimental research as the basis of natural sciences; and finally, the creation of technical high schools with the principle of the systematic application of scientific methods to the service of mankind."

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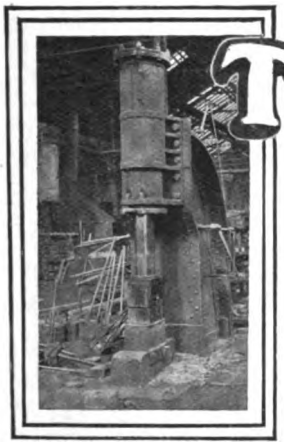
TECHNICAL EDUCATION FOR APPRENTICES.

By D. DRUMMOND, M.Inst.C.E., Head of the Locomotive Department on the L. & S.W. Railway.



TECHNICAL education, during the last few years, has occupied the attention of all who are interested in the manufacturing industries of this country. It is not my intention to deal with the systems adopted in America, France, Germany, and Switzerland, as these have been fully explained by Professor Dalby, in papers discussed at the meeting of Naval Architects, and at the Institute of Mechanical Engineers.* I wish to deal with the question from the points of view held by those who took part in the discussion at the meetings of the two societies mentioned, and to give your readers a short description of my own views on this important question, together with an outline of the guiding principles adopted by the London and South Western Railway Company in providing technical education for the apprentices employed in their works at Nine Elms. The views held and advocated by those interested in technical education differ widely as to the best means to be employed. Some prefer a continuous course from school to college, followed by workshops: others advocate the "sandwich system"—that is, six months in the workshop, and six months continuous teaching at a technical college: others again advocate that technical and practical training shall proceed hand in hand—and the latter system, I am fully convinced, will result in the greatest good to the greatest number.

Different Schemes of Training

Whichever system is adopted, it would, in my opinion, be helpful if the last year or two of the school work of the boy could bear some relation to his future calling. I do not mean that there is any need to alter the present curricula for boys who leave the public elementary schools at fourteen, having passed the seventh standard. Such boys have generally obtained a good grounding in arithmetic and elementary science, with instruction in drawing and manual training. I do, however, recommend the parents of boys in secondary schools, if they intend their sons to enter the profession of engineering, to see that the last year or two at school is not wasted in learning Latin and Greek, to the exclusion of any instruction in the principles of science, mathematics, and drawing.

School Preparation

My experience of the first of the three systems is not encouraging, nor do I think it gives a young man the best opportunity of attaining a thorough knowledge of his profession.

Few young men can obtain a knowledge of science before they reach the age of twenty or twenty-one years, and subsequently they must undergo at least three years' practical training. This I consider all too short a time to give them the all-round practical knowledge which will enable them to make the best use of their higher scientific training; and without this general knowledge the young engineer may be at a great disadvantage, should he be placed in a position of trust and find himself unable to thoroughly master the details of the duties he is responsible for.

Practical Training Necessary

No one finds out sooner than the workmen the capabilities of one in command over them; and if once they make up their minds that his knowledge is deficient, their respect for him is reduced, and his promotion is retarded, for want of the hearty co-operation of the workmen employed under him.

The sandwich system gives a young man a better chance to succeed than the system just referred to, owing to his being more in touch with both sides of his profession. I am informed on good authority that the American system of training from school to

* For these papers, I understand, we are indebted to the liberality of and interest taken in this question by Mr. Yarrow.

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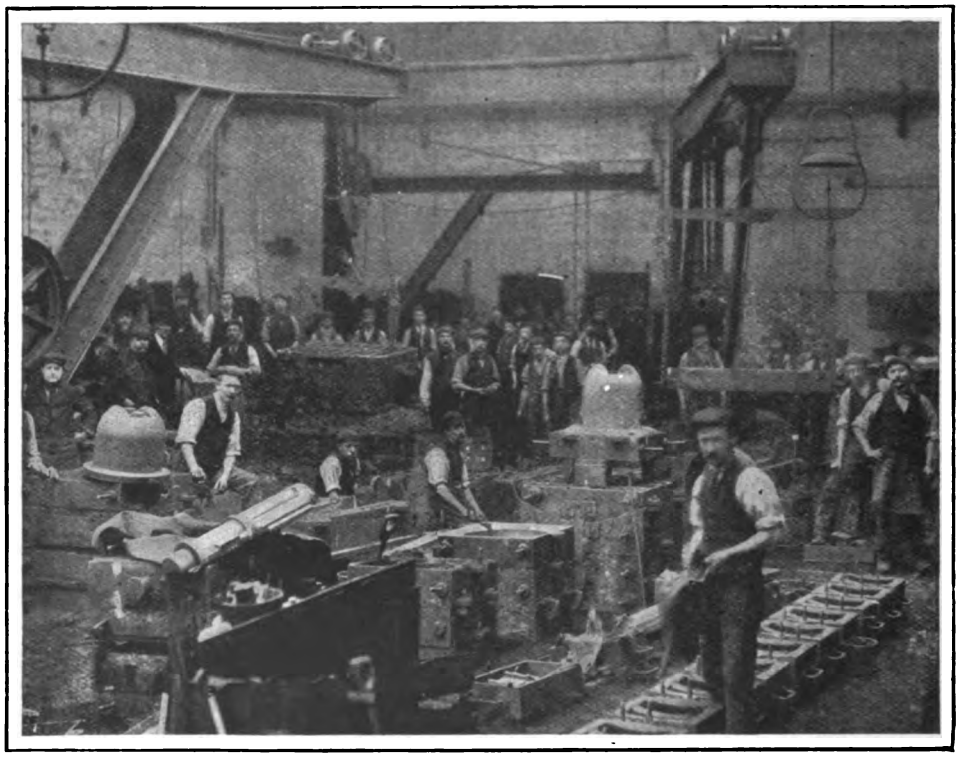
college, or on the sandwich system, has not proved a success, and an inquiry is now being made to find a better system than that at present in use. My informant's opinion was "that the sandwiches were too thick and they did not digest properly."

Age for Leaving School

After a long and wide experience in the training of apprentices, I have come to the conclusion that all lads intending to follow the profession of mechanical engineering, no matter what may be the position of their parents, should leave school at the age of sixteen years, having received a sound knowledge of the principles of mathematics and the elementary principles of mechanics and applied science, which are now generally taught in all our up-to-date day schools. This would ensure the proper foundation for the subsequent studies of young men who have the capacity to attain the higher scientific knowledge, placed so readily within their reach at the admirable technical institutions provided for that purpose.

I am no advocate for evening classes as a means of technical education although I fully recognise the enormous help they have afforded and are still affording. I am satisfied that the strain, both physical and mental, to which a growing youth is subjected, is likely to be dangerous to his health, if he is taxed by evening classes after a day's work in the shops, and it is quite impossible for him to be in a condition either of mind or body to make satisfactory progress under such conditions. An exception may perhaps be made in favour of drawing classes; but for such subjects as mathematics and mechanics, I am sure my remarks are true.



THE FOUNDRY AT THE NINE ELMS WORKS.
From a photograph; by permission.

With reference to the third system, that of concurrent technical and practical training, I do not know that it has been tried in this country, except in the Government dockyards and arsenals, or with a few apprentices here and there, until it occurred to me in September last to introduce it for the whole of the apprentices at our Nine Elms works. Having secured the cordial support of the Directors of the Company, I issued a notice signifying my intention of allowing all apprentices to attend classes during working

System in use at Nine Elms

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hours, the arrangements to continue for three years. At the end of this time the most promising and successful workers will be allowed to spend six months, in each of the last two years of their apprenticeship, as day students in an approved technical college. All class fees will be paid by the directors, and the wages of the apprentices will be paid as though in the workshop. It was at first my intention to hold the classes in the works, and to engage a special teacher; but, after consideration, it appeared more desirable to consider whether the work could not be undertaken by the nearest neighbouring technical institute, the well known Battersea Polytechnic, and I therefore entered into communication with its Principal.

Classes held at Battersea Polytechnic

As a result, the idea was taken up with the utmost enthusiasm and interest, and, with the approval of the Governors, arrangements were made to start the classes, even though commencing at the unusually early hour of 8 A.M. The first term's work is just concluded, and the results have so far exceeded my most sanguine expectations. In response to the notices published in the works, 136 apprentices presented themselves at the Polytechnic for the entrance examination, which consisted of a paper in mensuration, elementary mathematics, and mechanics. Seventy-four of the apprentices were considered to have passed and to be qualified to attend the classes; and the remainder were notified that they would be expected to reach the required standard by the next session.

The apprentices accepted were divided into two divisions, elementary and advanced. Each division has attended classes twice a week, once for one hour and once for one and a half hours.

The subjects of instruction are practical mathematics and mechanics. Home-work is set at each class, and weekly reports are sent to me recording any absences or unpunctuality and omission of home work. The apprentices are allowed to attend classes in mechanical drawing on one evening per week, so that this important subject is not included in the work of the morning classes. Unless absent from the class, the apprentices receive their wages as though present at the works from 6 A.M., although on one morning they do not reach the works until 9.30, and on the second morning at 10. The divisions attend the classes on different mornings, so that not more than forty-five apprentices are absent on any one morning, and their absence from work for the three or three and a half hours has caused no practical difficulties. The year's course will extend from September to the end of March or April, examinations being held at the end of the first term, and at the year's end. Apprentices who pass the annual examination with sufficient credit will proceed to higher work the following year, while the unsuccessful ones will be allowed to repeat their work for a second year, when, if again unsuccessful in the examination, they will drop out. The second year's work will consist of more advanced practical mathematics, and of lectures and laboratory work on steam and heat engines, for which subject it will probably be necessary to give time for a lesson of two hours and a half. At the end of the three years, as already stated, the most promising apprentices will be allowed to spend half the year in a technical college, and there is no doubt the company will be only too eager to engage them afterwards in positions of responsibility and trust, to which otherwise they would probably not have attained. Thus the system, when complete, would seem to promise that most desirable of all ends—the union of workshop and technical training: the granting of equal facilities for improving their technical knowledge to all apprentices when commencing their life work: the discovery, encouragement, and higher training of the most capable, and those likely to make "leaders;" with the no less important advantage of sifting out those who have reached their limit in scientific knowledge.

Report of the first Session's Work

The report from the Polytechnic is most interesting. It states that the students are seldom absent or late: that home work is regularly and well done: that the apprentices display an unusual interest and keenness in the work; and that in all these points they are considerably ahead of any evening classes. This means, that the work can be better co-ordinated, and got through more quickly and more efficiently, than with the too often unpunctual, irregular, tired, and "home work shirking" evening student.

The experiment, therefore, if it can be so termed, has succeeded beyond my utmost expectations, and I should like to express my appreciation of the enterprise displayed by the Polytechnic in taking up the work: of the enthusiasm and skill of Principal Wells in taking so personal an interest in the whole scheme, and in organising the classes; and of his assistants, Mr. J. W. Button, A.R.C.S., A.M. Inst. M.E., and Mr. J. Dobbie, A.R.C.S., in conducting them.

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Status of Apparatus

And now some account of the arrangements in our works for the practical part of the training of our apprentices will be interesting.

The apprentices employed at Nine Elms works are the sons of the employés of the company, and the period of apprenticeship is five years. The rate of wages at starting is 5*s*. per week, with an increase of 1*s*. per week every six months, subject to the recommendation of their foreman. The different branches or sections are as follows: —

Smith's shop.
Machine shop.
Fitting shop.
Erecting shop.
Boiler shop.
Pattern shop,
Iron foundry.
Brass foundry,
Millwright shop.
Paint shop.
Coppersmith shop.

The sons of workmen employed in the works usually follow the section of the work that their father is engaged on, but they are allowed the privilege of deciding what branch of the work they wish to follow. In all sections they commence at the beginning, and gradually advance step by step until they become qualified to undertake all grades of work in the special department they are connected with. Boys who show special intelligence, good conduct, and time-keeping, are encouraged to divide their time of apprenticeship between branches of work differing from that which they commenced on. Where possible, boys should be trained to at least two branches, such as turning, and fitting or millwright work; this gives them the advantage of more steady employment, since they can either take charge of a turning lathe, or work at the fitting bench.

A great misfortune in the education of apprentices has been the subdividing of the work into sections, preventing them from receiving an all-round knowledge. Apprentices in the boiler department must confine their attention to that class of work solely. They should be taught riveting, plating, and angle-iron work, and special attention should be paid in teaching them how to do repair work. This, in my opinion, is a most important part of the education of a boiler-maker who deals with high-pressure locomotive or marine boilers.

Apprentices in the erecting shop or fitting shops should have their time divided equally between the two departments. Apprentices in the pattern shop have their whole time confined to this branch of the work; the same with iron and brass moulders.

The blacksmith's department on railways gives no scope for apprentices to secure a sufficient knowledge, as the work is not varied enough to make them all-round proficient workmen, and it is very rare to have such apprentices in railway workshops.

Proposal by the Institute of Civil Engineers

I have great hopes for the success of the scheme proposed by the President and Council of the Institution of Civil Engineers, inviting the presidents and councils of kindred societies to appoint members to form a joint committee (including, I presume, representative members from the leading technical colleges in and around London) to look after and encourage the scientific education of our young men in all branches of science, and to stimulate special talent when brought to their notice. There is no one better qualified to preside over such a committee than the present President of the Institution of Civil Engineers, Sir William White.

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STRUCTURAL DESIGN.

PART II.

By E. FIANDER ETCHELLS, A.M.I.Mech.E.

THESE notes are not intended to form a complete or detailed exposition of any part of the theory of structures, but simply to suggest methods of study for the easy acquirement of the fundamental principles, and their application; they will, however, include an elementary amplification of certain fundamental propositions. My experience as a lecturer has shown me that such amplification is necessary when addressing those who may have studied architecture or building construction, but have not made a special study of mechanics.

No attempt will be made at defining such terms as force, matter, etc.; but a little space will be devoted to the fuller consideration of any terms which may be ambiguous or non-descriptive, such as moment of inertia in beam formulæ, or radius of gyration in column formulæ.

Since words are merely the expression of our thoughts, it is clear that a new thought can be presented to another person only by giving a new meaning to existing terms, or by employing new combinations of existing words. Thus it is that we have more ideas than words to represent them, and consequently confusion may arise.

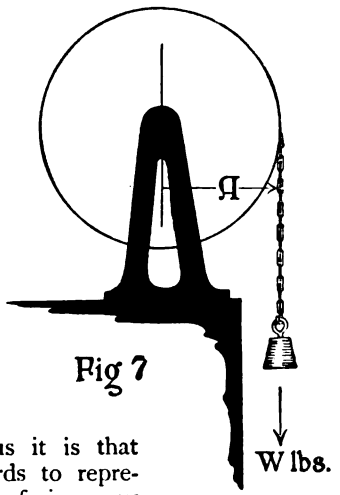

Fig 7

In engineering and mathematics we have several words which stand for more than one idea; thus, a second may mean a second of arc, or a second of time. By a tangent, we may mean the tangent to a curve—that is, a geometrical tangent; or we may mean the ratio of the perpendicular to the base in a right-angled triangle, *i.e.*, the trigonometrical tangent. At the very commencement of our study we come across the word "moment," which may mean a very small interval of time; or may mean importance, as in the sentence "it is a little matter and of no moment whatever." In mathematics the word "moment" almost invariably means "momentousness" or "importance." In Fig. 7 let the weight W be hung on the rim of the wheel. There is obviously a tendency to rotation in a clockwise direction. The tendency to rotation is proportional to the weight W, and also to the length of the arm or radius marked "A." Any quantity which is proportional to two separate factors is proportional to their product. The measure of the tendency to rotation is called the "turning moment" of the force, *i.e.*, the numerical importance of the tendency to turn about the given axis. The turning moment of a force is usually abbreviated to "the moment of a force." Let us now try to combine these separate concepts into one comprehensive definition.

The moment of a force about a point is equal to the magnitude of the force, multiplied by the length of the perpendicular drawn from the point to the line of action of the force. Thus, if the weight be 4 lbs., and the distance between the axis of rotation and the line of action of the force be 5 inches, then the turning moment, or the tendency to turn, will be 20 lb.-inches.

From this it can be seen that the tendency to turn is unity when the weight is 1 lb. and the arm is 1 inch, and 20 lb.-inches means nothing more than that the tendency to turn is twenty times greater than if 1 lb. were acting at a radius of 1 inch.

1 lb. at 20 inches: 20 lbs. at 1 inch; and 4 lbs. at 5 inches, all have the same turning moment. It is not necessary that turning moments should be expressed in inch-lbs. We might have adopted one ton acting at a radius of 1 foot, as our unit in measuring the tendency to turn. For laboratory experiments a small unit is desirable. For massive engineering structures a larger unit is more convenient. Suppose we have 1 ton acting at a radius of 1 foot: this would produce a turning moment of 2240×12 lb.-inch units.

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In beam calculations, engineers usually adopt ton-inch units. In these units 1 ton at a radius of 1 foot would be expressed as 12 ton-inches, *i.e.*, N ton-feet = (12 N) ton-inches. Suppose we have more than one force acting on our pulley, as in Fig. 8. If the moments in a clock-wise direction be considered positive, then moments in an anti-clockwise direction must be considered as negative. There is no tendency to rotation or revolution, when the algebraic sum of the moments is zero, *i.e.*, for equilibrium

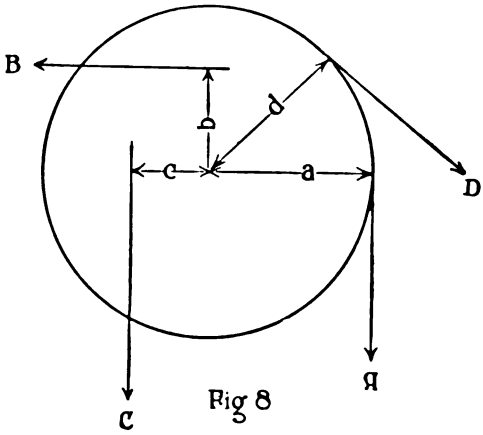

Fig 8

$$A.a - B.b - C.c + D.d = O \quad \text{(Eqn. No. 1)}$$

From equation 1 it can be seen that

$$A.a + D.d = B.b + C.c,$$

or, in words, the sum of the positive moments must be equal in magnitude to the sum of the negative moments.

Let us apply this principle to find the upward pressures or re-actions at the supports of a freely supported beam, as in Fig. 9. We know for a start that if there is an unbalanced tendency to rotate round any point whatsoever the beam will revolve around that point. In other words, since the beam is not rotating about any point, we know that the algebraic sum of the moments of the forces acting round that point must be zero. Thus, considering any point E, we know that

$$R_L.d + A.b - R_R.c = O \quad \text{(Eqn. No. 2)}$$

By adding $R_R.c$ to both sides of equation 2 we get

$$R_L.d + A.b = R_R.c \quad \text{(Eqn. No. 3)}$$

That is, the sum of the clockwise moments is equal in magnitude to the sum of the anti-clockwise moments. Suppose we consider the force to the left of E, the resultant moment for this portion will be $R_L.d$. Now this force will produce rotation in a clock-wise direction, unless the forces to the right of E produce a neutralising moment, *i.e.*, a turning moment equal in magnitude, but opposite in direction

$$R_L.d = R_R.c - A.b \quad \text{(Eqn. No. 4)}$$

This can be proven independently by subtracting A.b from both sides of equation 3. It was stated that we could use this method of moments for finding the value of re-actions at the right and left supports. To do this we must obtain an equation in which the re-action required is the only unknown quantity. We can accomplish this by causing R_L or R_R to vanish. R_L or R_R will vanish if we take moments about one end or the other. Thus, to find R_L take moments about R_R (see Fig. 9)

$$R_L.\text{span} - C.c - A\ a = O,$$

then by adding equal quantities to both sides of this equation, we obtain

$$R_L.\text{span} = C.c + A.a.$$

Then by dividing both sides of the equation by the length of the span we obtain

$$R_L = \frac{C.c + A.a}{\text{span}} \quad \text{(Eqn. No. 5)}$$

We can find R_R by taking moments about R_L.

We shall find that $R_R = \dfrac{C.d + Af}{\text{span}}$.

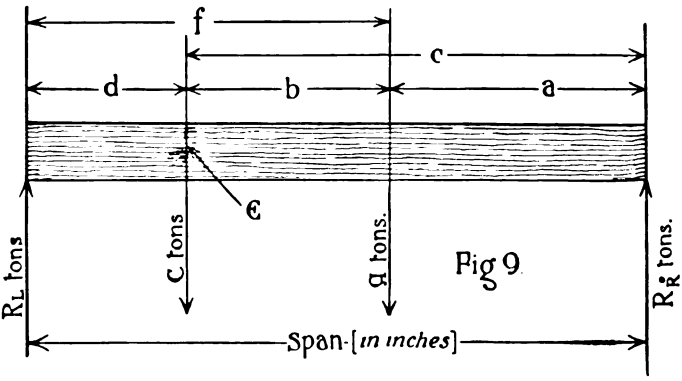

Fig 9

There is also another way of finding R_R when the value of R_L is known. Since action and re-action are equal in magnitude and opposite in direction, the total downward load is equal

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to the upward pressures of the supports, *i.e.* :—

$$C + A = R_L + R_R,$$
$$\therefore R_R = C + A - R_L.$$

The student has now been introduced to the two fundamental principles underlying the solution of all beam problems. These principles have not yet been specifically stated in this paper, as I believe it is better to use several of their particular applications before stating them in their widest and most general terms. When we have ascertained all the external forces on the beam, we can proceed with our investigation. These external forces cause the beam to bend ; the fibres on the upper side are thereby compressed, and the fibres on the under side are brought into tension. For any given cross-section of any

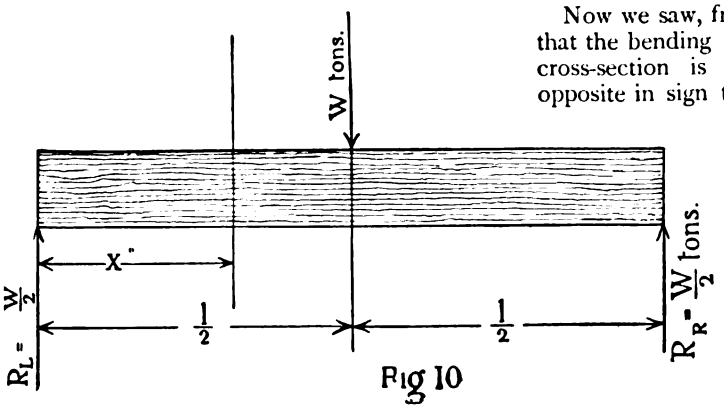

Fig 10

beam these induced internal stresses are proportional to the resultant turning moments acting in mutual opposition on either side of the section.

As these turning moments produce a bending of the beam, they are usually called bending moments, and this latter term will be used in our subsequent work.

Assuming that the beam has uniform depth and breadth, the greatest internal tensile and compressive stresses will act across that section which has the greatest turning or bending moments acting in mutual opposition on either side. Therefore, before we proceed further, we must find a means of discovering the part of the beam which fulfils this condition. There are many ways of doing this. One of the simplest is by means of cartesian co-ordinates, or graphic algebra, or the use of squared paper. [In the case of plotting bending moments, the terms become synonymous.] We first require a formula giving us the bending moment in terms of the distance along the beam.

We shall start with a very simple case.

Case 1 is a totally imaginary girder, assumed to have no weight, but capable of supporting a load of W tons, concentrated at the centre of the span : see Fig. 10. Let us consider the forces to the left of the section distant x inches from R_L. At x the bending moment $= \frac{W\,x}{2}$ ton-inches = B M.

When x = O the bending moment is zero.

When $x = \frac{1}{2}\,l$ the bending moment

$$= \frac{W}{2}\cdot\frac{l}{2} = \frac{W.l}{4}. \quad . \quad . \quad \text{(Eqn. No. 6)}$$

When $x = \frac{3}{4}\,l$ the bending moment

$$= \frac{W}{2}\cdot\tfrac{3}{4}\,l - \frac{Wl}{4} = \frac{Wl}{8}.$$

Now we saw, from our previous equations, that the bending moment to the left of any cross-section is equal in magnitude but opposite in sign to the bending moment to the right of the cross-section, so that the bending moment when $x = \frac{3}{4}\,l$ could have been found more simply by taking the forces to the right of the section thus :—

$$\text{B.M.} = \frac{W}{2}\cdot\tfrac{1}{4}\,l = \frac{W.l}{8}.$$

Let us now draw a line representing the span of the beam to some convenient scale. At various points along the beam erect ordinates representing the corresponding bending moments as shown in Fig. 11.

By calculating bending moments for intermediate points, we will find that the tops of the ordinates will all lie along the lines A B and B C in Fig. 12.

We see that to quickly draw the bending moment diagram for a central load on a

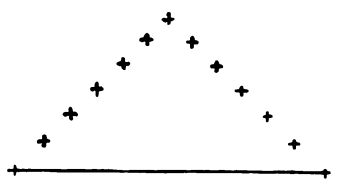

Fig 11.

girder freely supported, we need only draw a base line representing the span, and on the centre of this line set up a perpendicular representing the value of $\frac{W.l}{4}$, then by com-

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pleting the triangle and measuring the ordinates, we can always find the bending moments at any cross-section of the given beam. Let us take the case of uniformly distributed load resting on a beam of known weight. (see Fig. 13). We can readily find the bend-

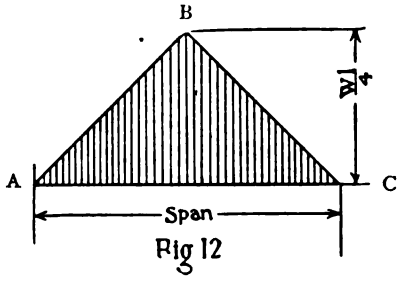

Fig 12

ing moment due to the weight on the beam, or the B.M. due to the weight of the beam itself, or the B.M. due to both taken together. We shall adopt the latter course.

Let W_L = the total load resting on the beam in tons.

Let W_B = the total weight of the beam alone.

Let $W = W_L + W_B = w.l$.

Let l = the span in inches.

Let x = any distance from the left re-action in inches.

Let w = the combined weight of beam and load per inch run.

Each re-action will be

$$\frac{W_L + W_B}{2} = \frac{W}{2} = \frac{w\,l}{2}.$$

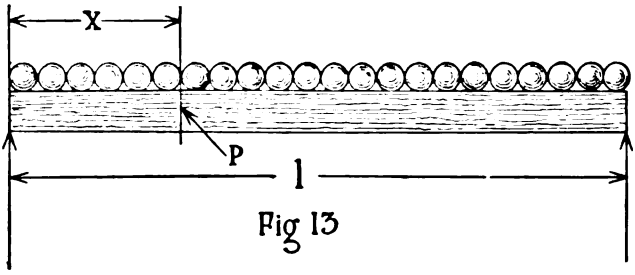

Fig 13

The portion of the load to the left of the point P may be taken as acting through its centre of gravity, which is at a distance of $\frac{1}{2}$ x from the point P.

Taking bending moments round the point P we have $\frac{W}{2}$ x acting in a positive or clockwise direction. Acting in the opposite direction we have w.x acting at an arm of $\frac{1}{2}$ x, giving a negative bending moment of $\frac{w\,x^2}{2}$.

The algebraic sum of the bending moments of the forces to the left of P is therefore equal to

$$\frac{W}{2}x - \frac{w\,x^2}{2} \quad . \quad . \quad . \quad . \quad \text{(Eqn. No. 7)}$$

The resultant of the bending moment of the forces to the right of P can be shown to have the same numerical value, but it will be found to be acting in an anti-clockwise direction.

When x = 0 B.M = 0.

When $x = \frac{l}{2}$ B.M. $= \frac{W}{2}.\frac{l}{2} - \frac{w}{2}.\frac{l}{4}$

$$= \frac{W\,l}{4} - \frac{W\,l}{8}$$

$$= \frac{W\,l}{8} \quad \text{(Eqn. No. 8)}$$

To find the bending moment due to the superincumbent load, or the B.M. due to the weight of the beam alone, it will be necessary to insert the value of W_L or W_B in equation No. 7 instead of W.

By means of the equation No. 7, a diagram can be constructed showing the bending moment at every part of the beam.

If we draw a line representing the span of the beam to some convenient scale, and on this base line set up ordinates whose lengths will represent the B.M. at the corresponding parts of the beam, our task is done. Let us take an illustrative numerical example, with figures which can be checked mentally.

Let y = bending moment in foot tons.
Let w = load per foot run = 2 tons.
Let l = 10 feet.
Let X = distance from left support in feet.
Let W = 20 tons = w.l.

Then $y = \frac{W}{2}X - \frac{w}{2}X^2$.

(Compare with Eqn. No. 7).

For this example we obtain the following values of x and y :—

Values of x .	0	1	2	3	4	5	6	7	8	9	10
Values of y .	0	9	16	21	24	25	24	21	16	9	0

Now plot these values as we did in the previous case. If we find the B.M. for other intermediate points, we shall find that the tops of the ordinates all lie along a regular curve. This curve has a particular form, and is known as a *parabolic* curve. It is given this name because it is the same shape as the section of a cone would have if the section

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plane were *thrown parallel* to one of the slant sides of the cone. It follows of necessity that the plotting of the bending moments caused by a uniformly distributed load on a freely supported beam must give a parabolic curve, because the equation representing the B.M. and the equation to this particular conic section have algebraically similar forms. Thus, suppose $y = bx^2$ where b is

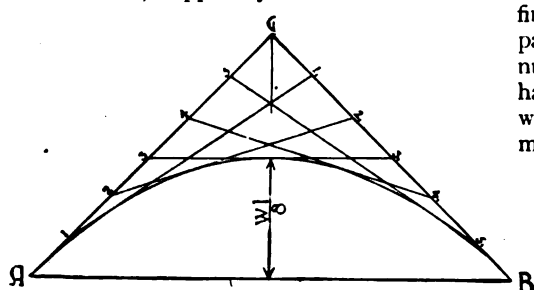

Fig 14

a constant. It does not matter whether x represents the number of pounds weight in a ship or the number of yards in a piece of cloth: when y is plotted the shape of the curve will be the same in all cases.

Now since we know that for a distributed load on a freely supported beam the B.M. diagram would be a parabolic curve, we can get this diagram without making a series of calculations. To do this we must draw a line representing the span of the beam, and on the centre of this line set up a perpendicular representing the bending moment at the centre of the beam, *i.e.*, $\frac{W\,l}{8}$.

We must now draw a parabola passing through the three terminal points thus given. There are many simple methods of doing this. I shall give one convenient, though approximate method.

Take the line A B in Fig. 14 representing the span. On the centre of this line set up an ordinate representing twice the value of $\frac{W\,l}{8}$. Connect the points A C and C B by two straight lines. Divide A C into any chosen number of equal parts: an even number of parts is preferable, but not essential. Divide C B similarly. Join 1 1, 2 2, 3 3, 4 4, etc. A regular curve drawn tangential to these lines will give the outline of the bending moment diagram.

These methods of drawing bending moment diagrams without calculating the successive values of the bending moment are very useful for our standard cases, but the student, who is only used to pictorial methods, will find himself in difficulties when he leaves the pages of his book of diagrams to take up the numerous awkward cases his employers may have in store for him. It is then that he will feel the advantage of the graphic algebra method. For so long as the student can express the bending moment from point to point of the beam by one or several separate equations, he will encounter no difficulty. With the purely pictorial or graphic methods we have too often to learn a separate rule for every case. With the graphic algebra method, we have only one underlying principle to remember. As a further illustration of this method, let us take the case of a beam loaded, as in Fig. 15. To find the left re-action, take moments about the right re-action.

$$R_L\,(\text{tons}) = \frac{12 \times 24\,\text{ft. tons} + 18 \times 9\,\text{ft. tons}}{36\,\text{ft.}}$$
$$= 12{\cdot}5\ \text{tons.}$$

B M at A = 12·5 tons × 12 ft. = 150 ft. tons.

B M at B = 12·5 tons × 18 ft. − 12 tons × 6 ft. = 153 ft. tons.

Taking forces to left of C the B M round C
= 12·5 tons × 27 ft. − 12 tons × 15 ft. − 9 tons × 4·5 ft. = 117 ft. tons.

Taking forces to right of C the B M round C
= 17·5 tons × 9 ft. − 9 tons × 4·5 ft.
= 117 ton-ft.

(To be continued.)

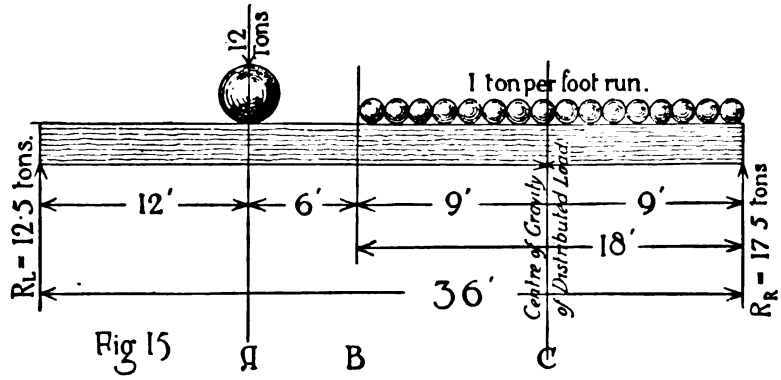

Fig 15

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INCANDESCENT ELECTRIC LAMPS.

PART I.

By JAMES SWINBURNE, M.Inst. C.E.

THE modern incandescent lamp consists of a thin wire or filament of carbon mounted in an exhausted bulb, and is apparently the simplest piece of apparatus possible. All the same, nobody knows half the things that are going on inside the innocent-looking bulb. The carbon is made by slowly carbonising a thread of homogeneous material. In early days paper and bamboo fibre were used. Bamboo fibre was never of very much use, but the early Maxim lamps, made of paper, were very good. Swan made more homogeneous material by treating knitting-cotton with sulphuric acid, of the right strength to parchmentise it. The action was necessarily incomplete, for the thread had to be strong enough to be drawn through the acid, and therefore could not be dissolved perfectly. The homogeneous material was really invented by Weston, of instrument fame. He made thin sheets of celluloid or nitrocellulose, like those now used for photographic films. From these, filaments were cut and then reduced by ammonium sulphide. The result of such a process is a material which is chemically cellulose, but physically structureless. Swan then squirted filaments. A solution of nitrocellulose was slowly expressed from a nozzle into a bath, which made it set. In this way beautifully uniform nitrocellulose thread was made. This material, made very much finer, is the basis of most of the artificial silks on the market. Powell next attacked the problem, and used a very smooth solution of cellulose in chloride of zinc, and squirted it. This saves the reduction, and makes a very good filament. This method is now in almost universal use. Other solutions, such as cellulose sulphocarbonic ether, made by treating cellulose with caustic potash and carbon disulphide, are also employed. The cotton is first dissolved in the chloride of zinc solution, and then expressed from a suitable glass nozzle into a solution which makes it set into a material looking something like a fine thread of hard-boiled white of egg. This is washed and dried. It shrinks into a material like catgut. This is wound for carbonising on frames which allow for the contraction. The frames are packed in powdered carbon to prevent any burning, and carbonised at a high temperature. The temperature is raised gradually to a white heat. If heated too rapidly, the carbons become crooked and weak. The carbons are next electrically heated one by one in an exhausted vessel, with a residuum of hydrocarbon gas. This has several effects. In the first place, the carbon is heated to a much higher temperature than in the furnace, and this hardens and consolidates it, and reduces its resistance enormously. The hot carbon decomposes the hydrocarbon gas, and carbon is deposited on the surface of the filament. This deposited carbon is very hard, and has a grey surface. The coating reduces the resistance of the carbon, and equalises it, because if the diameter is uniform, any part of the carbon which is of higher resistance becomes hotter, and therefore deposits more carbon. This equalising used to be of enormous importance. The carbons we used to make, in the early days of incandescent lamps, would light up unevenly, and the flashing would gradually make them uniform. Still earlier, the filaments would not start up with any pressure a dynamo of that date could give; so a large electromagnet was put in series with the filament, and the filament short-circuited through a shunt resistance; on breaking the shunt the self-induction produced a sudden current in the filament, and this started the action. Hence the term "flashing." Heating carbon electrically in a hydrocarbon was used by Sawyer and Mann in 1878, but the method of flashing under reduced pressure, for making incandescent lamp filaments uniform, is due to Maxim.

The Evolution of the Filament

Flashing

Flashing is no longer needed for making the filaments uniform along their lengths. For hardening them, over-running in vacuo is satisfactory. My own experience is that, though flashing is a great convenience for standardising filaments, each individual

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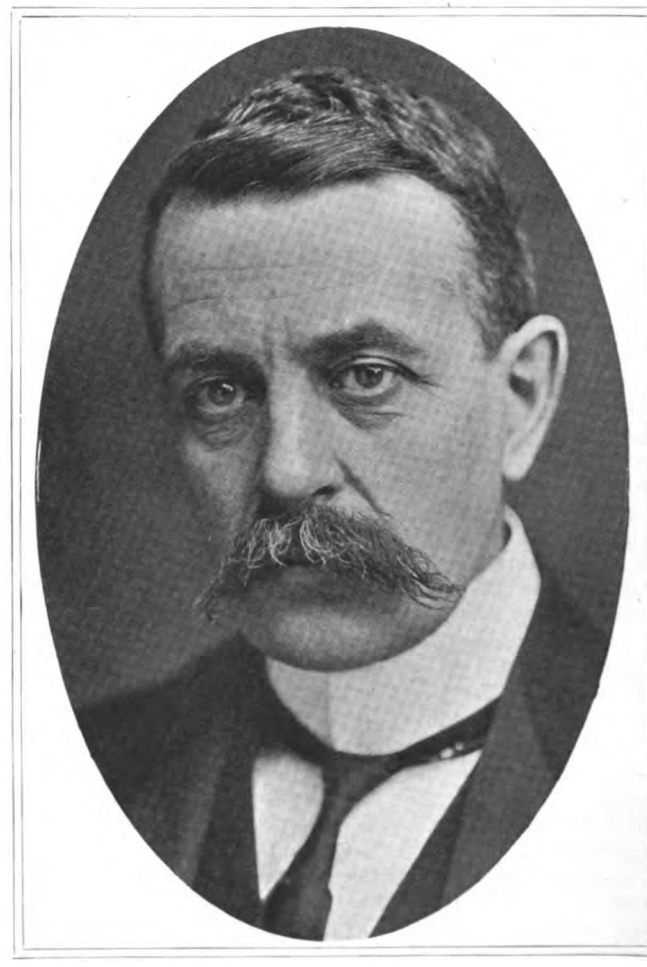
filament is better without it. The deposit also thickens the filament a little, and alters its candle-power. The reduction of resistance of a filament, other things being equal, is bad; for it means that for a given pressure and light the filament must be longer and thinner, and therefore weaker. Though a filament is very strong and resilient when cold, it is softer hot, and the carbon can then be bent by an electromagnetic field.

One of the commonest arguments in favour of flashing is that it increases the efficiency of the lamp. Of course, running at a higher temperature increases the efficiency, and if flashing enabled a higher temperature to be used without shortening the life, the argument would be sound. The idea is, however, that flashing provides a grey or whitish surface which has a special preference for giving out light, as opposed to heat, at a given temperature. The facts are, that if a given filament is run at, say, 10 candles and 30 watts with a black surface, and is then flashed so as to whiten the surface without increasing the diameter perceptibly, it will give 10 candles with less than 30 watts, and with 30 watts it will give far more than 10 candles. From this it is argued that the efficiency is increased. But the argument is quite unsound. The emissivity of a black is greater than that of a grey surface, which means that at a given temperature a black surface will radiate more power. If a given power per square millimeter is supplied electrically, the black body will settle down to a lower temperature and give off all the power, but a greater proportion will then be in heat. The luminous efficiency of a lamp under any conditions depends on the ratio of the light given to the heat. In an incandescent lamp there is no convection, so the power is all given out as radiant heat or light.

The behaviour of the lamp is perfectly in accordance with the dependence of efficiency merely on the temperature of the carbon, and its being independent of the nature of the surface. Suppose the lamp with the black filament gives 10 candles with 30 watts, and its temperature is normal. If it is now flashed to a grey colour, and run at the same temperature as before, as its emissivity is less, it will give less light and less heat, and take less electrical power. Instead of giving 10 candles and taking 30 watts at the standard temperature which gives reasonable life, it gives, say, 8 candles and takes 24 watts. It is an 8 instead of a 10-candle lamp. If it is now run up to 10 candles it is over-run, and therefore gives a higher efficiency: it is at a higher temperature, so a larger proportion of the power is given out as light. It thus absorbs less than 30 watts to give 10



JAMES SWINBURNE, M.INST. C.E.
Photo by George Newnes, Ltd.

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candles. If run up still higher, so as to take 30 watts, it will give out much more than 10 candles. If, instead of taking a grey carbon, a smaller black filament had been chosen, similar results would have been obtained; but no one would urge that small lamps were more efficient on such a ground.

Fallacies about selective efficiency have also run riot in connection with incandescent gas mantles. They are made of thoria, which is white, and when pure of low emissivity; generally a little of a coloured oxide such as ceria is added. If the mantle were quite non-radiating, or had no emissivity, it would get to the temperature of the flame just where it is immersed, which is very high, far beyond the melting point of platinum. The flame will melt a fine platinum wire at once, but the large wires people insert to measure the temperature by, do not get near the temperature. A non-emissive mantle at the temperature of the gas would give no light. Pure thoria gives very little. If its emissivity is increased by adding a very little coloured oxide its light increases, but its temperature falls. If too much ceria is added the temperature falls so much, owing to the good emission, that the radiation gets redder, and contains more and more heat, until finally a pure ceria mantle gives only a red glow and is at a comparatively low temperature, as it radiates energy so quickly that the flame cannot keep it very hot. There is thus a particular emissivity which gives the greatest light emission. As only a small portion of the energy of the gas is radiated, the maximum light emission is here the greatest candle-power per cubic foot per hour. All sorts of fanciful theories are constantly brought before scientific societies to explain this simple case. Ceria is supposed to act catalytically, whatever that means, or to vibrate continually from one state of oxidation to another, in defiance of the second law of thermodynamics. Ceria is really used, not because of any such action, but because it does not volatilise. Any other coloured oxide would do, so far as emission goes. Thus a pure alumina mantle gives little light until a little oxide of chromium is added. Then the green oxide makes the mantle too emissive, and it gives a red glow; but the oxides eventually combine into delicately tinted ruby, which is less emissive, and rise to a higher temperature, giving a good light.

Mantles

To return to our electric lamp: the filament is next cut to length and mounted on platinum wires and sealed into the bulb, which is then exhausted. In old days Sprengel pumps were considered to give the best vacua. Careful trials show that the Geissler gives the best results. A carelessly or badly used Sprengel will, however, give a better result than a badly used Geissler. It is probably for this reason that the Sprengel is generally employed in raw science laboratories. Oil-flooded mechanical pumps are much used in America. In 1882, I used Knowles steam pumps, which are made for sugar refineries, and are flooded with glycerine, for making the initial vacuum. Mercury pumps are such a nuisance on a large scale, that oil-flooded metallic pumps have largely taken their place. The Fleuss is a laboratory form of this type of pump Chemical vacua, that is to say, vacua produced by leaving a residual gas and then absorbing it chemically, have been proposed for the last twenty years. In exhausting a lamp, however, a good deal of gas has to be got off the glass, and some out of the filament and joints: it is popularly supposed to mostly come out of the filament, as carbon's property of condensing gases in its pores is well known, but in fact a great deal comes off the glass. The lamps are therefore "run" on the pumps, and cased in so that the whole lamp gets as hot as the glass will stand.

Methods of Exhausting

Perhaps liquid hydrogen may soon be used as a convenient means of exhausting. The lamp will then be sealed with a few inches of quill attached. The end of this will then be dipped into liquid hydrogen, which will condense all the gases and vapours, and the lamp will then be sealed off.

Use of Liquid Hydrogen

The finished lamps are then tested in batches, capped, packed, and sold.

A great many attempts have been made to supersede the carbon filament; but there are great difficulties in the way. Not only must the material be refractory, but it must have a high specific resistance: that of carbon is, in fact, too low for modern distribution. In early days 20-candle 60-volt lamps were as high as we could go. Bamboo lamps took 100 volts, but their efficiency was low, and their life short. Then 100-volt 20-candle lamps were produced by the Swan Company, and now we have got to about 250-volt 16-candle lamps. 250-volt 5-candle lamps can now be obtained. The filaments are so exceedingly thin that they are supported in the middle, or two filaments are mounted in series in one globe. The thinness of the filaments is important, not only from the point of view of

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mechanical strength, but also because there is a sort of surface erosion going on inside the bulb of an incandescent lamp. This gives rise to increase of resistance, and as it is a surface effect, a thin filament increases very quickly in resistance. But in addition to this, the erosion is very much greater in a high-pressure lamp, other things being equal. For these reasons, high-pressure lamps are very inferior to low, and there is no compensating advantage in the lamp itself. The high pressure, however, is a great benefit to the supply companies, because it enables them to distribute at reasonable cost, so far as leads go. The change from 100 to 200 volts on consumers' premises, which has recently been taking place, is thus at first sight wholly against the interest of consumers. In fact, it is not so at all, for the consumers have really to pay for the mains, so that, in the long run, it pays them better to have high pressure lamps.

We are so accustomed to it, that we scarcely realise that the incandescent lamp has settled the pressures of supply for us. It was to suit the old lamps that 100 volts became the standard pressure. It was a very bad pressure for arcs, as there was too much for one and too little for two. Crompton introduced 110 volts, so that two of the ordinary 50-volt arcs could be run in series, with a controlling resistance in circuit. Now that we have 200 and 250-volt lamps, we have raised the standard pressure accordingly. Probably 500 volts on the three-wire system will be the standard in future.

Voltage

Another rule made in favour of the incandescent lamp is the constancy of pressure. Variations of pressure of, say, ten per cent. each way would not give much trouble with motors, or even with arcs, but with carbon lamps it is destructive. The limits of pressure are therefore limited by law to four per cent. each way, or eight per cent. altogether. Even this large variation causes the supply companies great inconvenience. If lamps could be made which were not sensitive to reasonable variations of pressure, electrical distribution would be simplified, and the cost of energy reduced.

Fine iron-wire resistances are used in series with Nernst glowers, and they are available for carbon incandescent lamps. Iron increases in resistance enormously, as its temperature changes in passing through one narrow region. At one current value, the resistance of an iron wire in a bulb of hydrogen under very slight pressure thus increases enormously for a very small increase of current. If the iron wire is taken of the right size, and so on, for a given incandescent lamp, the lamp can be run in spite of considerable variations of pressure, as the variations are taken up by the iron. The whole lamp, including the wire, can then be run at a higher efficiency than the lamp alone. It is possible some such system as this will come into use first for tramways and railways, and then for power circuits where uniform pressure is too expensive to be maintained.

Many attempts have been made to improve the ordinary carbon lamp. People have tried to coat the carbons with special substances which have a predilection for emitting an extra proportion of light. The commonest idea is to coat or mix the carbon with oxides of rare earths. The rarer the earths the more scientific the inventions sound. Unfortunately, not only is there no foundation for these theories of selective emissivity, but all known oxides are reduced by incandescent carbon.

Metals have been tried as substitutes for carbon. Platinum obviously will not stand the temperature. For the last few years a great deal has been heard about an osmium lamp, invented by Auer von Welsbach, of incandescent gas-mantle fame. It has some obvious drawbacks. Osmium is expensive, but it may become cheaper if there is a demand for it. The highest oxide of osmium is very volatile and very poisonous; whether this gives trouble in the manufacture I do not know. Another difficulty with metal lamps is the low specific resistance. When the length and fineness of a 200-volt carbon filament is considered, a metal wire of the same, or nearly the same surface and resistance seems unpractical.

Substitutes for Carbon

The Osmium lamp is now on the market in Austria. It is made for about 33 volts as a rule, and 25 candles upwards. The 33-volt lamp has two wires in series, each being supported in the middle. The price is five shillings net. At the efficiency given, of about two-thirds of a candle per watt, it saves the extra cost in a very short time. The drawback is the low pressure. The makers supply three-wire inductive regulators for alternating circuits. These add to the cost and complication. For large lights above 75 candles, where three lamps can be used in series, the Welsbach electric lamp has a good outlook. With low pressures, for carriage lighting and so on, lamps of 10 volts

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and 5 candles can be got for three shillings. This field is necessarily small.

I have tried experiments with some metals with the idea of making a sort of sponge of metal and oxide, having enough metal to conduct metallically, and enough oxide to give a high resistance. Molybdenum and tungsten, at the temperature necessary for a candle per watt, or near it, melt into little globules. Thorium is more promising. According to the periodic law, thorium and titanium ought to be refractory. The resistance I obtained was too low also.

Various other schemes have been discussed. It is a favourite idea to coat the carbon with silicon or boron. The silicon is deposited by electrically heating the filaments in tetrachloride of silicon. I tried this in 1885, but got no satisfactory results. Langhans has, however, worked the subject out much more thoroughly, with what result I do not know. My idea was to coat the filament with silicon, not to make a silicide of carbon or carbide of silicon. I believe Langhans's notion was the same. For a year or so Moissan's experiments were in fashion, though not so vulgarised as radium; and, after the discovery of calcium and other carbides, people attacked the problem of carbide lamps. It does not follow, however, that a filament is a carbide because the inventor thinks it is. I have tested so-called carbide filaments which were nothing but carbon, burning away completely in the air. Some carbides, such as silicon carbide, are very difficult to burn, as the silica formed protects the rest. Even a pure carbon filament needs a high temperature to burn it. Other carbides, such as zirconium carbide, burn like tinder, a spark running along and leaving an ash of zirconia. The making of carbide filaments is exceedingly troublesome. Many of them are decomposed by the moist air of a room, and there is thus difficulty of handling. There is also great difficulty in mounting a filament or rod that is to run at a temperature, to give a candle or so a watt. It would be no use trying to make a carbide lamp unless it promised some such efficiency as this, since, in order to oust the carbon lamp, it must be very much better. A new invention that wants a great deal of working out has against it all the experience and knowledge gained in the old manufacture; so, unless it is very much better on the face of it, it is not worth while troubling about it.

Carbide Lamps

ENGINEERING AND CIVILIZATION.

Nature for December 31st contains a report of a most interesting lecture delivered at Oxford by Professor Perry. With great literary ability Professor Perry contrasts the actual education given to the youths of our ruling classes—an education confined to the study of languages and methods of thought which have been dead for nearly two thousand years—with the education which would fit these youths to govern a country dependent for its future existence on the excellence of its technical industries. The following passages occur in the course of the lecture:—

"Are you aware that in one ton of coal there is as much energy, as much actual work, as may be done by forty thousand good labourers in a ten hours' day? Our best steam-engines utilise only one-tenth of this energy at the present time. But even now we know that the cost of the most unskilled work done by man is one thousand times the cost of the same work wherever it may be done by the best steam-engines. One fact of this kind properly considered is worth many long essays about the effect of the engineer in altering all the character of our civilization. It is labour that is the true standard of wealth. The steam-engine has added incalculably to the wealth of the world. We forget that man is no longer needed for unskilled labour, so that when we use unskilled labour we are using the materials which God has given us in the most inefficient manner possible. Furthermore, it becomes sweated labour, it unduly taxes skilled labour, it starves invention, and it brings up base, ill-fed families.

* * * * *

"The truest stories about man are the fairy stories; they are true of all times, of all races of men, and the truest fairy story is that which tells how men who look back and not forward are turned into lumps of rock or pillars of salt."

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THE HEATING AND VENTILATION OF AN EDUCATIONAL BUILDING.

PART I.—HEATING.

By W. W. F. PULLEN, A.M.Inst.C.E., M.I.Mech.E., Wh.Sc.

MUCH of the unsatisfactory state of many educational buildings is due to want of method in their inception. When a building has been decided upon, an architect is instructed to prepare plans, which are eventually adopted. The contract is let, and the foundation-stone laid with great ceremony. The fabric grows apace, and is nearing completion when some one suggests that a staff will be necessary in the near future, and forthwith advertisements are sent out. There is no external evidence that it ever occurs to anyone, that the arrangement of a building for educational purposes needs the aid and advice of an experienced organiser, and preferably the one who is eventually to be entrusted with the working of the institution. There appears to be a general ignorance of the fact, that from the preliminary drawings to the completion of of the contract, technical advice and supervision is constantly required, and can only be satisfactorily given by one who has had practical experience in teaching and organisation.

Let me give an instance of the sort of thing that frequently occurs. A school has to be built very close to a main thoroughfare, perhaps within a few feet of it. The fact that carts and drays continually pass along the street, and will eventually render the lecturer's voice inaudible, does not appear to be considered; the lecture rooms are placed next to the main street, resulting in great annoyance to lecturers and students alike. This is emphasised in the summer months, when the temperature of the rooms often necessitates the opening of windows.

Again, rooms set apart for drawing are not infrequently situated in some dark corner where artificial light is a necessity at mid-day. Reading-rooms and rooms for private study are often placed near a workshop, where the noise of hammers, the racket of an engine, or the hiss of escaping steam, renders real study practically impossible.

A heating apparatus is often installed that is ineffective, inconvenient, and so badly arranged that repairs are carried out with great difficulty, while ventilation is often non-existent. It is with heating and ventilating that this article proposes to deal.

There are three methods of heating a large building economically—by hot water, by steam, and by hot air. Hot water is used in many buildings where there is no steam required for lighting or power purposes; but a large number of schools possess their own lighting plants, and then it is more economical to employ steam as the vehicle for distributing heat to the different rooms and corridors, though hot air may be used with the extra advantage that it provides ventilation as well. Warming by hot water is generally a slower process than by hot air or steam, because the rate of radiation of heat depends to a certain extent on the rate of circulation of the water in the heating pipes, and this cannot well exceed certain limits, which are soon reached.

The temperature of the radiating pipes is lower in the case of hot water than in that of steam, and as a consequence the unpleasant smell of frizzled paint is not so evident with the former as with the latter, though in neither ought it to be serious after the first few days. Some people declare that any system of heating other than the open coal fire is more or less objectionable, but its extravagance in both fuel and labour prohibits its adoption, even if it possessed the superiority attributed to it.

It is not always recognised that it is the duty of schools in which engineering is studied to generate their own electric light, as the machinery employed forms an excellent working example for both class work and experiment.

Heating by steam is carried out by connecting pipes in each room with a boiler, suitable valves being introduced wherewith to regulate the supply of steam.

The idea is simplicity itself; but, unless put into practice with due regard to the physical laws involved, the unfortunate individual whose business it is to supervise the working of the plant must expect a very uncomfortable time indeed.

The pressure of steam in the mains and radiators or heating coils is seldom permitted

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to exceed 15 lbs. per sq. in. by the gauge, or 30 lbs. per sq. in. absolute. When the steam supply is taken from an ordinary high-pressure boiler, it is reduced in pressure automatically, as it flows into the heating system, by means of a reducing valve (Fig. 1). A pressure much greater than 15 lbs. per sq. in. would tend to cause leakage, which is unpleasant in any form; and, speaking generally, the cost of construction and maintenance would be considerably increased, though how much, only experience could determine.

But there is no necessity at all to use pressures higher than 15 lbs. per sq. in. from the heat-transmission point of view, and the balance of evidence is in favour of lower pressures. The following Table indicates the reason at a glance —

TABLE OF PROPERTIES OF STEAM.

Pressure of steam in lbs. per sq. in. absolute.	Temperature of steam F°.	Sensible heat, or heat in 1lb. water.	Total heat of formation of 1lb. steam.
1	102	70	1,113
5	162	131	1,131
10	193	162	1,141
15*	213	182	1,147
20	228	197	1,151
25	240	209	1,155
30	250	219	1,155
100	328	298	1,182

* Atmospheric pressure.

The third column indicates the amount of heat, reckoned from the freezing point, that 1 lb. of water can convey to a heating coil, while the last column gives the total heat which can be conveyed to a radiator and given out during the condensation of 1 lb. saturated steam. At 30 lbs. per sq. in. absolute, or 15 lbs. per sq. inch above the atmosphere, the total heat of 1 lb. of steam is 1,158 British thermal units, while at 5 lbs. above the atmosphere it is only 7 units less, and at the atmospheric pressure only 11 units less. Hence the heat-carrying capacity of steam at all pressures used for heating purposes is approximately the same. It therefore matters little as regards heat-carrying capacity whether the steam be at the atmospheric pressure, or 15 lbs. above it, or even 85 lbs above it.

It will be noticed, on reference to the second column of the table, that the temperature varies considerably with the pressure; and although a great difference of temperature between the steam in the radiator and the atmosphere of the room tends to promote a rapid flow of heat into the latter, this high temperature is somewhat unpleasant to people sitting in the immediate neighbourhood, and thus the space near the radiator cannot be used to advantage. The dust of the room settles freely on the radiator, and is constantly being brought into contact with it by convection currents produced by the radiator itself. The temperature of a high-pressure radiator bakes this dust, which gives off an unpleasant odour during the process.

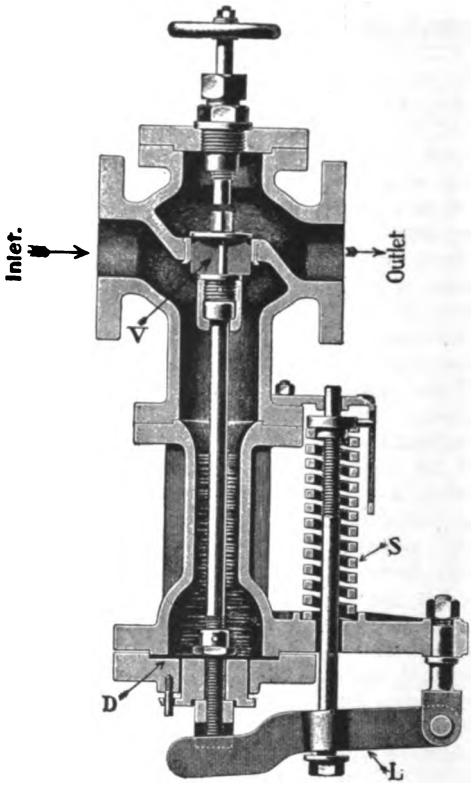

FIG. 1.—REDUCING VALVE.

Pressure of inlet steam tends to open valve V by urging it upwards, and to close it by pressing on diaphragm D. The spring S acting through lever L tends to open valve V, while outlet pressure tends to close it. Steam can pass only when pressure on outlet is less than that on inlet side, by a definite amount.

The balance in favour is so far all on the side of low-pressure steam. But the steam has to be transported to the radiators or heating pipes, or rather it has to convey itself, and it is not always clearly appreciated how this must be accomplished.

Assume that the pipes and radiators contain nothing—not even air. If steam of, say, 15 lbs. per sq. in. above the atmosphere is turned into the pipes, it will flow rapidly

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from the region of high pressure to the region of low pressure, filling the pipes and radiators; and if the remote end of the piping is not closed in some way, the steam will escape freely into the atmosphere. This waste is prevented by providing the remote end of the main with a steam trap (Fig. 2) of which the function is to permit the water to escape freely, but not the steam.

The whole of the steam mains and radiators are then at the same pressure, and water can drain away if the piping is arranged with a sufficient fall towards the steam trap. As steam condenses in a radiator, more steam moves up to take its place, and the process goes on so long as there is a supply from the boiler.

So far we have assumed that the apparatus is devoid of everything but steam. But air is dissolved in all tap water, and this air is liberated as the water is heated, so that there must be steam *and* air in all the steam mains and radiators.

The presence of air is undesirable from the heat transmission point of view, as it conveys less than one-thirtieth of the amount of heat which is conveyed by the same weight of steam, and it is a bad conductor into the bargain.

Further, if it collects in a radiator, it is not easily displaced by the steam, as the latter practically enters by diffusion, the system being all at one pressure. This diffusive action is much retarded by the small and tortuous passages through which the steam often has to pass before entering the radiator.

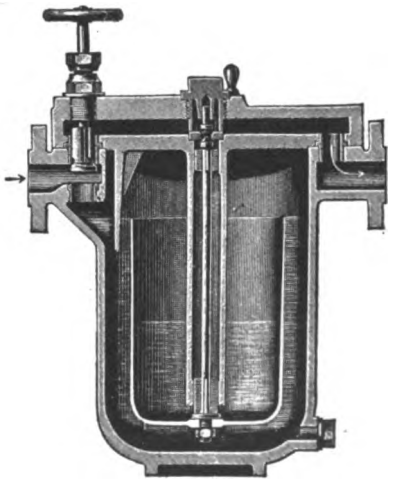

FIG. 2.—STEAM TRAP.

Condensed steam enters trap on left, floats the interior cylindrical vessel, and finally overflows into the latter. When sufficient water has entered, the vessel sinks and drags down the valve at the top of the central channel. The steam pressure forces water up the central channel until cylindrical vessel again floats and closes valve.

Some means of escape for the entrapped air must be provided, and for this purpose a little air cock is inserted in the end of the radiator, remote from the entering steam. When the radiator is full of steam, the high temperature of the latter causes a metal cylinder to expand and close the air cock (Fig. 3). When air is in the radiator, its lower temperature causes the cylinder to contract, thus leaving an orifice at which the air can escape.

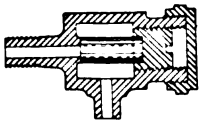

FIG. 3—AIR COCK.

Air cocks are not an unqualified success; in fact, they can only be looked upon as necessary evils. They require constant attention, and fall an easy prey to the combination of youthful ingenuity and a penknife, by the aid of which latter they are put out of adjustment with startling facility. They sometimes become very troublesome and almost inoperative if the steam pressure varies considerably, for air gradually accumulates as the steam is condensed. A drop in pressure permits the air in the radiator to expand and completely fill it, together with the neighbouring pipes, causing what is known as "air-logging." Of course this ought not to occur if the air cocks worked properly, but it is a fact that it does occur, and then the air must be removed by re-adjusting the air cock. An increase of pressure will sometimes produce the same result. As the air cock is closed by the expansion of a small piece of metal not more than an inch long, the wonder is that it works so well as it does.

The diffusion of steam through air along a small pipe is a very slow process. Air logging is much emphasised if the pipes are laid with slight depressions, forming pockets, in in which water can collect (Fig. 4). It is not an infrequent occurrence to find a radiator full of water. This is generally due to bad setting of the pipes. Water hammer is due to the same defect, and often becomes so troublesome as to stop a lecture.

Mr. Strohmeyer showed very clearly, a year or two ago, how steam pipes may be fractured by water hammer, due to pockets in which water collects.

If the scheme of piping is carefully arranged, so that both water and air can easily gravitate away out of the system, no serious trouble should be experienced, while water hammer would be entirely avoided.

There is a system, as suggested earlier in

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this article, in which steam at atmospheric pressure is used most effectively and efficiently, especially where non-condensing engines are running on the premises. The exhaust steam from these engines, or failing that, steam from a boiler, reduced in pressure to that of the atmosphere by being passed through a reducing valve, is led through pipes to the radiators. Each radiator has an inlet stop valve and a special steam trap at the outlet, and is connected to a return main, which conveys the air and condensed steam back to a closed reservoir in the neighbourhood of the boiler. A pump is connected to this reservoir for the purpose of extracting the air and condensed steam which returns from the radiators, thus incidentally reducing the pressure in the return main some few pounds per sq. in. below that of the steam in the radiator. The result is that this difference of pressure between the supply and return mains produces a positive flow through the pipes and radiators altogether independent of gravity or diffusive action, while the little traps permit the air and water to readily escape. Since air is more dense than steam, especially at the low pressures used in such a system, the air is always extracted with the water, and air troubles do not exist.

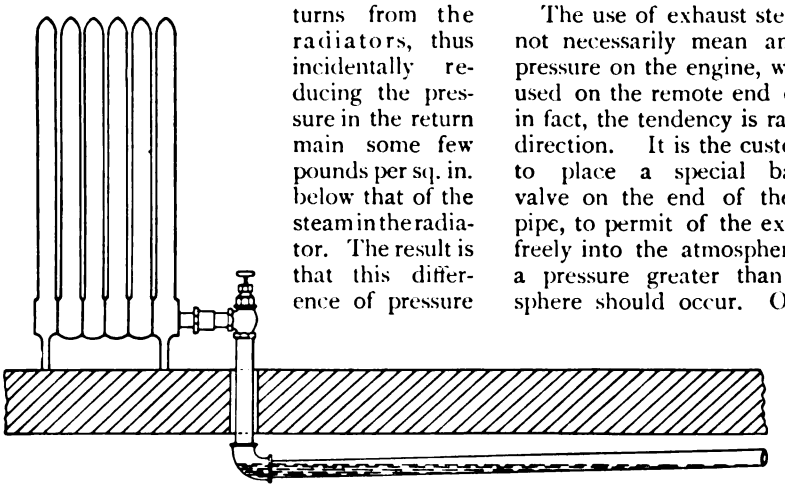

FIG. 4.—FORMATION OF POCKET IN STEAM PIPE WHICH SLOPES IN THE WRONG DIRECTION, SO THAT WATER CANNOT DRAIN AWAY.

Further, on account of the positive flow, produced by a definite difference of pressure, smaller pipes may be used, and the apparatus can be readily handled, with greater certainty of action. The stop-valve on each radiator permits of easy regulation of the flow of steam into the radiator, and consequently of the rate at which the room is heated; while, should it be unnecessary to warm the room, the radiator may be turned off without fear of water-logging or water-hammer through leakage of steam past the valve.

If a joint should become loose, leakage must take place inwards, on account of the partial vacuum in the return pipe, while the pressure in the supply main is only that of the atmosphere. The little steam-traps (called by the makers "thermostatic valves") require to be maintained in good order, but this is not a difficult matter.

When the engines are not running, steam is supplied from the boiler through a reducing valve. Some makers arrange for this to be done by a special valve, so that directly the engine is started the supply of steam from the boiler is cut off.

The use of exhaust steam for heating does not necessarily mean an increase of back pressure on the engine, when an air-pump is used on the remote end of the return main; in fact, the tendency is rather in the contrary direction. It is the custom of some makers to place a special balanced non-return valve on the end of the ordinary exhaust-pipe, to permit of the exhaust steam passing freely into the atmosphere if by any means a pressure greater than that of the atmosphere should occur. Other makers, on the other hand, do not use such a valve. Heating systems are sometimes arranged to take steam from the exhaust-pipe of an engine *without using an air-pump* on the return main. A pressure greater than that of the atmosphere by about 5 lbs. per sq. in. is then used in the heating-pipes, and this acts against the engine. Even then the exhaust steam generally proves economical from the heat point of view; but the engine must be somewhat larger than would otherwise be necessary, and the system must not be expected to work so satisfactorily or so cheaply as when an air-pump is attached.

The chief features of the atmospheric pressure or exhaust steam system are—

(1) The use of exhaust steam which would otherwise be wasted when engines are running.
(2) The absence of leaks.
(3) Easy and certain regulation.
(4) No water-hammer.
(5) Absence of air or water-logging, even if the pipes are not laid so as to allow water to drain away.

(*To be continued.*)

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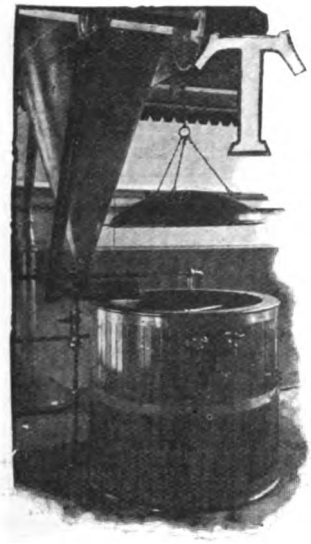
THE BACTERIOLOGY OF BREWING.

PART I.

By JAMES GRANT, F.C.S.

AN introduction to the study of micro-organisms in their relation to the Brewing Industry, as presented to the Students of the Brewing Department of the Municipal School of Technology, Manchester.



THE Chemical Department of the School of Technology is under the supervision of Professor W. J. Pope, F.R.S., qualified men being given charge of the various sections, such as (1) general and physical chemistry; (2) bleaching, dyeing, and calico printing; (3) brewing; (4) metallurgy; (5) paper making.

The brewing section is an important one, and, owing to its general equipment, excites the interest even of the casual visitor. The suite set apart for its study consists of lecture, preparation, and instrument rooms, a technical laboratory, as well as one devoted to water analysis, and the actual brewhouse—containing a well-arranged working model of four bushels capacity. Attached to the brewhouse are malt, hop, and sugar stores, while in the basement of the school is a cellar for the finishing of the beers produced.

The malt-rolls and the hot-water tank are placed on the upper platform. On the middle platform are the grist-case, attached to a mash tun by a Steel's masher, a wort-cooler, and a Vuylsteke converter. The lower platform on the one side of the brewhouse is occupied by a wort-copper and sugar vessel, and on the other by the fermenting vessels, above which is the refrigerator.

The ground floor is taken up by the driving machinery, barrel-washing plant, and other apparatus.

A notable feature is the equipment of the brewing and instrument laboratories, on which much care has been bestowed to render them suitable for the complete study of micro-organisms such as may be found in the air, water, worts, grains, and finished products of a brewery. This part consists of specially designed microscope tables, culture cupboards, sterilising apparatus, thermostats, incubators, a large refrigerator, and other necessary appliances for work: these are far too numerous and highly technical to be of general interest to any but those engaged in this entrancing study. Some few of the more important will, however, be described and illustrated in the course of these articles.

The courses of study in the Day Department extend over a period of three years.

A GENERAL VIEW OF THE MODEL BREWERY.

From a Photograph.

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The first is quite general; the second partly general and partly technical; the third is nearly wholly technical, and requires special knowledge on the part of the students. Some few men devote a large portion of their time in the fourth year to brewing research, a subject which offers an almost unbounded scope.

Amongst the necessary subjects of study, biology and botany occupy an important position, because the forms of life spoken of as micro-organisms or bacteria belong to the lower forms of plant life.

Micro-organisms

Botanically, they come under the great sub-kingdom of the Cryptogamia, or those plants which reproduce their species by hidden means, or by processes other than those common to the flowering plants belonging to the sub-kingdom of the Phanerogamia.

All are fungi belonging to the sub-kingdom Cryptogamia, or the non-flowering plants. This sub-kingdom is divided into three chief sections and seven classes.

The sections are: –

(i.) *Thallophyta*, which contains thallous plants devoid of leaves, stems, roots, and vascular bundles, and includes two classes: (*a*) the Fungi, which are devoid also of chlorophyll; (*b*) the Algae, containing chlorophyll.

(ii.) *Bryophyta*, containing mosses furnished with leaves and stems, but devoid of true roots and vascular bundles. It also includes two classes: (*a*) the Liverworts; (*b*) the Musci, or feather-mosses.

(iii.) *Pteridophyta*, containing the vascular cryptogams: plants furnished with leaves, stems, true roots, and vascular bundles. The section comprises three classes: (*a*) the *Equisetinae*, or horse-tails; (*b*) the *Lycopodinae*; (*c*) the *Filicinae*, or ferns.

Of all the seven classes, one only, the fungi, comes under the consideration of the student of micro-organisms. For convenience, this class may be further subdivided into (*a*) *Schizomycetes*, or fission fungi, and (*b*) *Eumycetes*, or branching fungi.

The *Schizomycetes* include also the *Schizophycetes*: the mode of reproduction of the *always unicellular* fission-fungi is effected by sub-division, hence their name.

The *Eumycetes*, or branching fungi, include the moulds and mucors (the *Hyphomycetes* or Fungi proper) and the yeasts (*Saccharomycetes* or *Blastomycetes*).

In ordinary brewing parlance, the members of the Fungi class are spoken of as bacteria: yeasts and moulds are also known by these names to the general public. Collectively, they are often termed organised ferments.

Bacteria are the smallest of all known living things. They are unicellular, the cell-wall being composed of a form of cellulose which encloses a mass of fluid protoplasm. So far, no cell nucleus has been found in any bacteria.

Schizomycetes (Bacteria)

Three forms are recognised :—

(*a*) Spherical or billiard-ball shape—ex. a coccus.

(*b*) Rod-shaped—ex. a bacillus such as *subtilis*.

(*c*) Spiral or corkscrew shaped—ex. a spirillum.

The Modes of Reproduction

Under favourable conditions all bacteria reproduce by splitting off, or fission, the two parts either separating or hanging together in chains or clusters. The spherical forms are the only bacteria capable of splitting up in more than one direction.

A considerable number of bacteria form spores possessing great refractive properties, and hence they glisten brightly when seen under a high-power microscope. The spores are formed in the interior of the organism, and are therefore termed endogenous. Bacilli frequently spore, but cocci very rarely.

Another method is by the continuous development of the rod lengths and fission.

Chemical Composition

Chemically, bacteria are composed of a covering or cell-wall of fungus cellulose, and internally of an aqueous solution of a very complex body known as protoplasm. According to Von Mohl (1844) this latter is a viscous, tough, elastic, transparent, and frequently granular, highly active nitrogenous body, built up of carbon, hydrogen, oxygen, nitrogen, sulphur, and traces of phosphorus. It is probably the most primitive organic substance known,

DIFFERENT FORMS OF MICRO-ORGANISMS. *A*, Micrococci (Frankland). *B*, diplococci (Fred Hentrich), *C*, streptococci (Fred Hentrich), *D*, staphylococci (Fred Hentrich), *E*, *F*, *G*, bacilli (Frankland), *H*, spirilla (Frankland), *K*, mycoid (Green Gluten, Freudenreich), *L*, yeast cells (Frankland), *M*, cornea bacilli (Frankland)

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forming the animate and, so far as can be ascertained, the ultimate basis or unit of all organic life, and was defined by the late Professor T. H. Huxley as the "physical basis of life."

Cellulose, on the other hand, is what is termed a carbohydrate body, containing carbon and the elements of water. It is closely related to cotton-fibre, paper, and similar substances, but in a number of cases the cell-wall contains very little true cellulose. Many bacteria either contain or generate a colouring matter, the pigment Bacterio-purpurin. Very few of these, however, exist in the brewery or its products, and hence are of little interest in the brewing world.

Some groups of bacteria possess the power of locomotion, which is brought about by very fine hair, or whip-like organs termed *flagella*. These flagella are usually so fine that they can only be detected when stained. The cocci or spherical forms as a rule are non-motile.

Irregular forms occur commonly in old cultures, and render it very difficult to recognise the different bacteria by appearance alone. This irregularity is caused by the deterioration of the cells: such are the involution forms. In size bacteria vary greatly, but all are microscopic. Those occuring in the brewery range between 0·2–4 μ in diameter. The symbol μ, which is used as a standard of measurement in this subject, is a thousandth ($\frac{1}{1000}$) of a millimetre, and is known as a micron.

One metre	= 39·37079	English inches.
One millimetre	= 0·0393708	,, ,,
One micron	= 0·0000393708	,, ,,
$\therefore \mu$	= $\frac{1}{25400}$ of an inch.	

As the number of bacteria in nature is practically unlimited, it is necessary for the purposes of study to have some kind of classification.

One simple and useful is as follows:—

(1) The bacteria of fermentation, including Lactic, Acetic, Butyric, Viscosus, etc.

(2) The bacteria of putrefaction, as *Termo*, *Subtilis*, etc.

(3) Those which produce pigments, as the *Sarcina*, etc.

Another classification:—

(1) Pathogenic or disease-producing — ex. *B. typhosus*, *coma*, etc.

(2) Septic or putrefactive—ex. *B. subtilis*, etc.

(3) Zymogenic or fermentative, as the Lactic, etc.

(4) Chromogenic or pigment-forming, as *Micrococcus prodigiosus*.

Cohn's classification, according to normal appearance:—

(1) Sphaero-bacteria, as the cocci forms.
(2) Micro- ,, as the rod forms.
(3) Desmo- ,, as the thread forms.
(4) Spiro- ,, as the spirilla forms.

The rounded or oval forms are cocci.

When they exist in single cells they are	micrococci.		
,, ,,	pairs of cells	,,	diplococci.
,, ,,	chains of cells	,,	streptococci.
,, ,,	clusters of cells	,,	staphylococci.
,, ,,	packets of fours	,,	sarcina forms.

Naegeli includes the whole under the term *Schizomycetes*.

Media Foods

The most suitable nitrogenous foods are—peptones, amides, and similar organic compounds, ammonia, ammonium nitrate, and even nitrates. Some few can take nitrogen from the air.

The available sources of carbon are—carbohydrates generally, glycerin, fatty acids, alkaline salts of tartaric, citric, malic, and many other organic acids.

Effect of Air.

Bacteria are either aërobic, anaërobic, or transition forms. Aërobic bacteria are those which require air for their development and well-being. Anaërobic varieties thrive better in the absence of air, while some forms are transitional—that is, they develop during one portion of their existence in air, and another portion in the absence of air.

Action of Re-agents

Acids as a rule act injuriously, and either check or kill bacteria. Alkalies and alkaline bodies in weak solution, on the other hand, act as stimulants. *B. Typhosus* is an exception, since it can convert acid into alkaline media. Light has a similar action to acids, and has a powerful effect, especially on pathogenic germs.

Effect of Temperature.

The members of the *Schizomycetes* group require a much higher temperature to enable them to carry on their life functions than do the members of the *Eumycetes*, but different varieties require different temperatures. They can develop between 10–60° C. Those which occur in the brewery flourish between 20–35° C. Many of the pathogenic germs thrive well about blood-heat (37° C.).

It is well known that if milk is maintained below 10° C. (50° Fah.) it remains sweet for a considerable time, proving that lactic or milk bacteria require higher temperatures.

The temperature suitable for spore formation varies greatly with the different species, and, moreover, many bacteria require a free access of air (oxygen) during sporulation.

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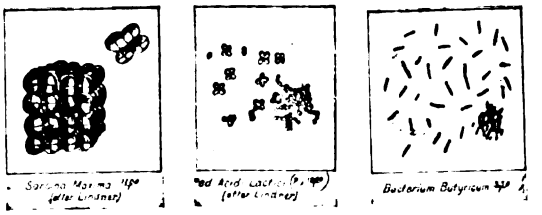
Electricity and pressure appear to affect bacteria only very slightly.

A great variety of products is evolved during the life action of bacteria. Among them are hydrogen, nitrogen, carbonic acid, sulphuretted hydrogen, marsh gas, alcohols, acids, alkalies, and such deadly nitrogenous bases as the ptomaines. The processes by which these products are formed probably resemble some form of hydrolysis.

Decomposition Products



To distinguish between bacteria, the following points should be observed:—

(1) The most suitable media or food supplies.

(2) The stages of development, and appearance at each stage.

(3) The products of decomposition.

(4) The behaviour towards oxygen.

(5) The modes and rapidity of multiplication.

(6) The influence of light and temperature.

(7) The action of antiseptics and other re-agents.

(8) The motility or non-motility.

All bacteria in a brewery are looked upon as harmful or injurious, and producers of disease in waters, worts and beers: but of all groups none are so dangerous as the anaërobic.

Of the micrococci or spherical forms the *sarcina*, of which there are many varieties, are the cause of bad odours, flavours, and cloudiness, especially when present in large quantity in beers. The writer has frequently found such forms in certain Swedish and German beers.

The *Pediococci lactici* induce the formation of excess of lactic or fixed acidity in beer-worts and beers.

The *Pediococcus viscosus* of Dr. Paul Lindner is the cause of ropiness in worts.

Of the rod-shaped forms or bacilli, the lactic bacteria, of which some half-a-dozen different forms exist in breweries, are particularly noxious. Butyric bacteria also occasionally exist in English and other beers. They produce butyric acid and stench.

There are also many different groups of acetic bacteria which rapidly convert weak alcoholic solutions into acetic acid.

Several rod-shaped forms of the viscosus ferment exist in beers, causing ropiness.

Another rod-shaped organism is the putrefactive ferment *B. subtilis*. It regularly occurs with lactic and other bacteria in diseased beers. Of the putrefactive bacteria the most important is that group known as *termo*. There is a large number of species recognised; but recently it has been suggested to group the whole under the term putrefactive bacteria. They are the probable cause of the disease termed "stinkers" which occurs in brewers' dirty casks, and bring about the decomposition of albuminous bodies, generating noxious gases, such as ammonia, sulphuretted hydrogen, etc.

In concluding this short account of the bacteriaceae, it would be well to point out that—

(*a*) There are enormous numbers of bacteria present in air, water, and other bodies, *which are of a beneficent character*, and by their life action we are enabled to live on the earth's surface.

(*b*) Only a very superficial and inadequate account of such an enormous and far-reaching subject can be given in so short an article. A perusal of Mr. Conn's excellent little book on bacteria, and also of Professor Percy Frankland's "Our Secret Friends and Foes," would be profitable.

For scientific purposes the reader should consult manuals on the subject, of which there are hundreds.

For brewing purposes, Hansen, Jorgensen, Lindner, Pasteur, Schützenberger, Sims Woodhead, Lafar, and other authorities may be studied.

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The Hyphomycetes.

This family includes all forms of mould or thread fungi, sprouting or budding fungi, and similar organisms.

The members are very numerous, microscopic, parasitic, and attack both living and dead bodies. For example, over thirty species attack the plants of the order of the *Graminaceæ*, or grasses; and about a dozen cause potato diseases. The *Hyphomycetes* are divided into a number of smaller groups or orders, and these again into genera, species, and varieties. An interesting order of this family is that of the *Mucedines*, and a genus of it known as the *Peronospora*. This genus includes all the rusts, smuts, brands, and mildews which attack the grain-bearing plants. The mycelial threads are branching, and the spores are of two kinds: the one borne on the tips of the branches; and the other, which is larger and globular, is borne on the creeping mycelial threads. The botanical name of these two plants comes from a Greek word signifying mildew, and is the *Erysiphe* or *Oidium*. To a brewer the latter name is very familiar, for not only is it connected with history, notably that of the famous researches of the late Professor L. Pasteur on the diseases of the vines, which almost destroyed the wine industry in the south-east portion of France; but it comes home to him in his own domains. *Oidium lactis* produces in his worts and beer lactic acidity, and this causes a hardness which is decidedly unpleasant. Another group of the *Hyphomycetes* comprises the moulds and mucors. So far as fermentation is concerned they are unimportant, although many possess the power of inducing alcoholic fermentation and generating carbonic acid and other bodies. These moulds are the most highly organised of the microscopic fungi. The containing cell-wall is a form of cellulose which yields no colouration with iodine solution, while the protoplasm is usually free from nuclei, and contains neither starch nor chlorophyll granules. The growth takes place by elongation of the cells, forming hyphae, which latter are sub-divided by transverse diaphragms of cellulose known as the septa. Aggregations of hyphae give rise to a thallus. The thallus is constructed of a general network of mycelial threads, of which the aerial hyphae are the spore organs. (See p. 175.)

Oïdium

According to Pasteur, moulds are normally aërobic, but the necessary amount of free oxygen is almost infinitesimal. The effect of it, however, on the growth in some few instances is remarkable. For example, *Mucor racemosus* forms a thallus when grown on the surface of liquids or semi-fluid bodies, but if submerged in a liquid it forms spherical cells—the gemmae—larger than, yet not unlike yeast-cells. This alternation of generation is referred to as *polymorphism*.

Mould fungi can flourish on very concentrated media, such as would readily check both yeasts and bacteria.

Foods of Moulds

It is well known that preserves made with too little sugar are liable to undergo fermentation and attacks from moulds. Some grow in alkaline solutions and others in neutral or even acid solutions.

Naegeli has shown that certain moulds can decompose and assimilate a number of antiseptic compounds.

Sugars and carbohydrate foods generally are suitable media to supply moulds with carbon.

The mineral matter required consists of potassium and magnesium phosphates, potassium and calcium sulphates, and some chlorides. For a supply of nitrogen, soluble albuminous compounds, peptones, amides, imido groups, ammonium salts, and even nitrates are pressed into use. The chemical composition varies somewhat with the media supplied. Thus Sieber showed, in his researches on *penicillium*, various *apergilli* and *mucors*, that this chemical composition is as follows:—

	Grown on Sugar and Gelatin.	Grown on Sugar and Ammonium Chloride.
Total solids	15·02 %	14·31 %
Water	84·98 %	85·69 %
Of the solids was found—		
Soluble in ether	18·70 %	11·22 %
Soluble in alcohol	6·91 %	3·38 %
Nitrogenous	29·89 %	28·90 %
Cellulose	39·58 %	55·78 %
Ash	4·91 %	0·70 %
	99·99	99·98

Temperature.

The limits of temperature vary greatly for the many different moulds, mucors, etc. The extremes lie between 2·5° C.–45° C. The following are suitable:—for *penicillium glaucum* and a number of the *mucors*, from 17°–21° C.; the *Oidium* group, between 18°–35° C.; some few of the *Aspergilli* like rather cool temperatures, say about 10°–15° C.; others flourish better between 28°–40° C.

The processes differ considerably with the different genera and groups.

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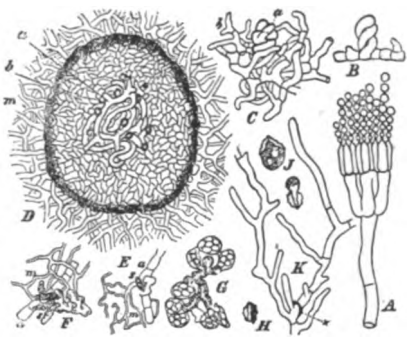
(*a.*) One of the simpler methods is by continuous budding and dividing off —a process allied to the budding of yeasts and their fission. The members of the *Oidium* genera reproduce by this means :—

Modes of Reproduction

(*b.*) By the formation of naked spores at the ends of the aerial hyphae or conidia-bearers. These spores are conidia. *Penicillium glaucum* is a good example of this process.

(*c.*) By the formation of spores in a special receptacle or sporangium, the walls of which burst and allow the contents to escape. Some of these spores possess hair-like cilia or flagella. These are the so-called Zoospores. *Mucors* usually reproduce by this method. The above three processes are recognised as vegetative or asexual modes of reproduction.

(*d.*) By sexual conjugation. Two threads or hyphae join one another (copulation) and give rise to a large spore—a zygospore — a kind of fruit body, from which the mycelial cells grow at a later period, after the zygospore has dropped from the parent mycelium. A number of the moulds and mucors reproduce by sexual conjugation.



PENICILLIUM GLAUCUM. AFTER BREFELD.

A, Conidia-carrier ; *B*, organs of generation ; *C*, structure of the growing body (*a*, the further developing carpogonium ; *b*, sterile threads) ; *D*, very young, growing body in section (*a*, ascogeneous hyphæ ; *b*, sterile portion of the growing body ; *m*, mycelium) ; *E* and *F*, ascogeneous hyphæ (*a*), with young tube structure (*s*), and sterile mycelial threads (*m*) from a more developed growing body ; *G*, group of tubes with spores ; *H*, spore ; *J*, germinating spore ; *K*, young mycelium (with spore at *x*).

It should be noted that the spores formed by any of the afore-mentioned processes are very resisting both to desiccation or drying, and to high temperatures. They frequently lie dry for years, but, if brought into a suitable food medium, immediately begin to develop.

All mould fungi are dangerous, both in maltings and breweries. The simplest way to keep them in check is to apply a frequent washing of bisulphite of lime.

Barley is attacked by *Penicillium glaucum*, *Mucor mucedo*, *Aspergillus glaucus*, various *Fusarii*, etc.

Hops are prone to suffer from attacks of the members of the *Oidium* group, and also of the mucor species.

Brewers' and distillers' worts are liable to the ravages of *Oidium lactis*, *O. dematium pullulans*, which latter renders the worts viscid ; *Penicillium glaucum*, *Botrytis cinerea*, *Monilia candida*, and others.

Brewers' grains are attacked by *mucors*, lactic ferments, acetic organisms, various *aspergilli*, etc.

For the microscopical examination of mould organisms only very moderate magnifications are necessary –from forty to two hundred diameters is ample.

As these germs are so common in the brewery atmosphere and products, a short description of a few of the more important may not be out of place.

A mould which is common almost everywhere —on preserves, in worts, sugar solutions, barley, in dirty casks, etc. It develops as a white mycelium, bearing aerial hyphae, and on the latter the conidia-bearers. At the ends of these are the naked spores or conidia, which form the characteristic bluish-green powder, and this evolves the mouldy aroma.

Penicillium glaucum

In the aërobic condition it forms carbonic acid and water. In the anaërobic state it sets up fermentation with beer-wort, forming traces of alcohol accompanied by a mouldy smell and flavour.

Erotium Aspergillus glaucus is a mould with closely woven mycelia, while the hyphae are colourless. These latter carry short, straight conidia-bearers, the conidia of which give the brilliant orange-yellow to sage-green tints so well known. It is very common on foods. Closely related to the *A. glaucus* are the Koji ferments, which possess the power of hydrolysing and fermenting carbohydrate bodies of the polyose group, such as starches and dextrins. Another member of this group is *A. oryzae*, which is the ferment of rice-beer so common in Japan and neighbouring eastern countries.

Eurotium Aspergillus glaucus

Mucor mucedo is a mould with white or greyish mycelium, from the lateral branches of which spring the aerial hyphae carrying the sporangium. Unlike *M. racemosus*, another common member of the family, it does not, when submerged in beer-worts and other nutrient fluids, reproduce by gemmation. *M. mucedo* is a frequenter of rotten fruits, old yeast, damp grain and malts, old bread and the like, often associated in

Mucor mucedo

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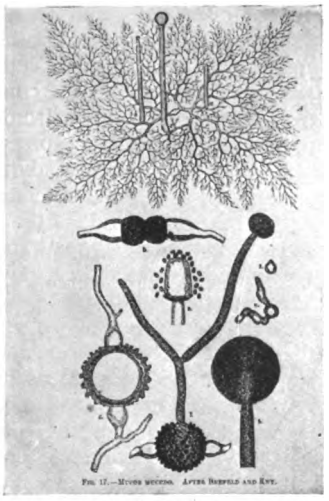
mouldy bread with the *Micrococcus prodigiosus*, which produces the phenomenon of *bleeding bread* owing to the bright red cells of this bacteria. The writer has often found it in the damp, mouldy bread lying about in some of the Manchester bakeries.

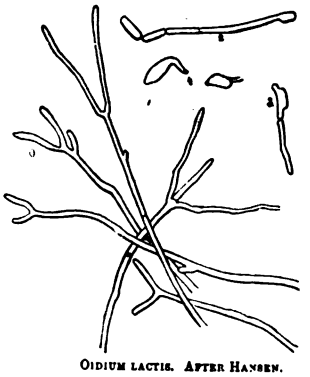
Fusarium hordeii is a member of the mycelium, divided by septa. Pieces fall off (fission), and these reproduce.

Oidium lactis

It occurs quite commonly in milk, brewers' and other grains, on pressed yeast, bakers' yeast, etc. There are many varieties of *Oidium*, as already stated, but



MUCOR MUCEDO.



OIDIUM LACTIS. AFTER HANSEN.

1, Hyphæ with forked partitions at the ends, and commencement of development of side branches; 2—4, conidia with germinating filaments, in 2 the germinating filament is already divided again into conidia, in 3 the conidium has given rise to a smaller and a larger germinating filament, the latter of which has separated itself at the point of formation; 4, two conidia, resembling yeast-cells in shape, beginning to germinate.

mould fungi which commonly exists on barley, and hence its name. When grown in a sugar medium it produces a beautiful delicate pink-coloured mycelium. On barley its peculiar crescent-shaped spores are characteristic.

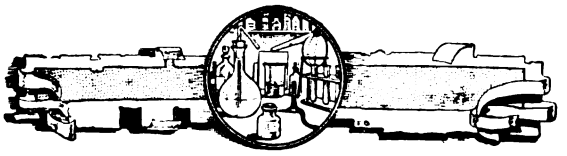
Fusarium hordeii

Oidium lactis is an organisation of low type which produces a beautiful snow-white

none are more interesting to study than the variety *O. lactis*.

Other fungi of importance are *Monilia candida*, *Chalasa mycoderma*, *O. dematium pullulans*, *Cladosporium herbarum*, *Thamnidium elegans*, *Botrylis cinerea*, *M. stolonifer*, *M. spinosus*, *M. racemosus*, *A. niger*, *A. flavus*, *A. herbariorum*, etc.

(*To be continued.*)



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THE CONTINUOUS-CURRENT DYNAMO.

PART II.

By H. M. HOBART, M.I.E.E.

SO far as regards the determination of its *cross-section*, the electric conducting circuit of the armature is designed mainly with reference to the current output of the machine. The *length* of the electric conducting circuit depending upon the mean length per armature turn and the number of turns—is determined not only by the voltage required of the machine, but also in great measure by the relative proportions which should be given to the armature strength (expressed in armature ampere-turns per pole) and the magnetic flux.

So far as concerns the specified voltage at no load, it is merely necessary to comply with the requirements expressed in the following formula—

$$E = 4\ T\ N\ M \times 10^{-8},$$

in which

E = Electromotive force.

T = Armature turns in series between positive and negative brushes.

N = Periodicity of reversals of the magnetic flux in the armature core, expressed in complete cycles per second.

M = Magnetic flux linked with the armature turns T.

As E and N are given, it remains to determine the suitable relative values for T and M, these quantities relating to the electric conducting, and the magnetic circuits respectively. If T is chosen great, M will be small, and the design will require a great expenditure for copper and a small expenditure for magnetic material. When T is chosen small and M great, the conditions will be reversed. One may readily see, in a general way, that for current prices for copper and iron, some one relation of T and M will correspond to minimum cost, due regard also being paid to the outlay for labour and for the materials required for mechanical purposes, as distinguished from the so-called "effective material."

It is the dynamo designer's task to devise designs complying as nearly as possible with this most economical relation. Sometimes thermal, and sometimes commutation considerations will stand in the way of employing the otherwise most economical proportions. The subject is by no means simple; for the present it will suffice to state that, in general, the lower the rated speed the nearer may the most economical design be approached, so far as relates to freedom from commutation difficulties. At high speeds the commutation limits require wide departures from the most economical proportions. The present understanding of the ventilation of dynamos has largely extended the limits of choice so far as relates to the thermal side of the question; nevertheless it is still in general the thermal limit which is encountered at low speeds. Considerations relating to regulation and also to efficiency sometimes impose restrictions, especially at very low speeds, and it may occur that a machine must be designed both unnecessarily cool, and with unnecessarily excellent commutation, and at considerably more than the most economical cost, simply in order to comply with some requirement relating to efficiency or regulation.

The considerations above indicated go right to the root of the real questions of dynamo design. For their further development it is, however, necessary to first set forth the principles relating to the design of the magnetic circuit.

B.—THE MAGNETIC CIRCUIT.

In the 400 kilowatt design, which has served as example in explaining the methods and calculations employed in designing the electric conducting circuit, the flux M may be estimated as follows:—

The voltage drop in the armature circuit at full load

= C R = 730 × 0·026 =	19·0 volts
Do. at brushes	2·0 „
Do. in compound winding (assumed for the present)	3·0 „
Total internal drop =	24·0 volts

Internal voltage = Terminal voltage + Internal (C R) drop

= 550 + 24 = 574 volts.

T = Turns in series between brushes = 99.

N = Periodicity in cycles per second $= \frac{100}{60} \times \frac{8}{2} = 6{\cdot}67.$

$$E = 4\ T\ N\ M \times 10^{-8}.$$

$$574 = 4 \times 99 \times 6{\cdot}67 \times M \times 10^{-8}.$$

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$$\therefore M = \frac{57{,}400{,}000{,}000}{4 \times 99 \times 6{\cdot}67}$$
$$= 21{,}800{,}000 \text{ c.g.s. lines}$$
$$= 21{\cdot}8 \text{ megalines.}$$

(1 megaline = 1,000,000 c.g.s. lines.)

21·8 megalines is the flux which enters the armature and becomes linked with the turns of the armature winding.

In the electric conducting circuit, the conductors are the seat of losses so long as current flows in them, but the magnetic flux occasions no losses in the magnetic material so long as it is constant in magnitude and direction. In the iron of the armature, its direction is, however, reversed as a point on the armature revolves from one pole to the next, a complete magnetic cycle corresponding to each pair of poles. There are also hysteresis losses in the pole faces, due to the slight oscillations in direction of the magnetic lines corresponding to the varying local reluctance of the magnetic circuit as the teeth and slots successively sweep by a given point. With these losses in pole face and in armature, due to so-called "hysteresis" (*i.e.*, the pure magnetic losses), are also associated very considerable losses due to "foucault" currents, these being simply secondary currents induced by the varying flux. The "foucault" current losses may be decreased by the employment of laminated structures. A customary thickness for the sheet-iron or steel employed is 0·5 millimeter, and, for the armature, every other sheet is generally coated on both sides with a japan varnish to insulate it from its neighbours. Care is also taken to avoid the use of bolts running from end to end through the armature core, or in any way to form closed circuits so located as to become the seat of secondary currents as the result of magnetic flux variations.

Many designers attempt to estimate these iron losses in accordance with fundamental electro-magnetic laws. Such attempts are as a rule very unsuccessful, and empirical estimations are ultimately resorted to in most cases.

In Fig. 14 is given a core loss curve compiled from observations made upon twenty-three continuous-current machines of widely different sizes and speeds. The curve has been found to give a fair approximation in most cases, although its merits are based more on its simplicity than on its accuracy. Cases, however, rarely arise where core losses deviate more than 25 per cent. from the values given by the curve, and great as this variation must be admitted to be, it is believed that no greater accuracy is obtainable by any commercially practicable method. Indeed, the quality of iron employed varies, sometimes in the same delivery, to as great an extent as this.

To illustrate the use of the curve, the core loss of the 400 kilowatt dynamo may be calculated.

Periodicity in cycles per second = N =

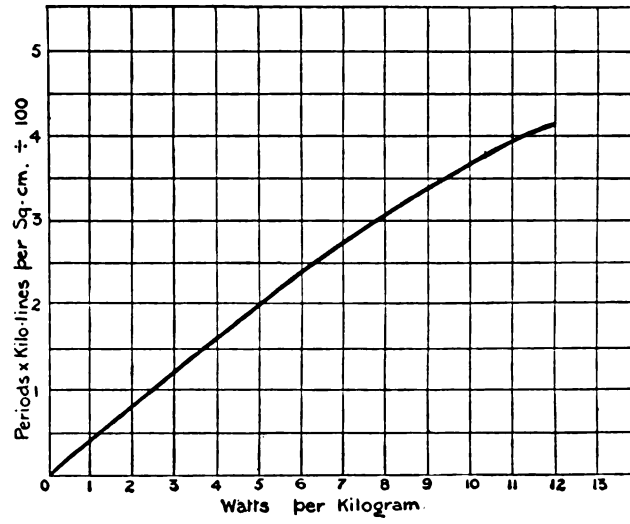

FIG. 14.—CORE LOSS.

revolutions per second × number of pairs of poles

$$= \frac{100}{60} \times \frac{8}{2} = 6{\cdot}67.$$

External diameter of armature laminations = D = 230 cms.

Internal diameter of armature laminations = d = 140 cms.

Area of laminations, including slots = $\frac{\pi D^2}{4} - \frac{\pi d^2}{4}$ = 41,500 − 15,400 = 26,100 sq. cms.

Area of slots . . . 1100 sq. cms.

Net area of laminations . 25,000 sq. cms.

λ_n (Net iron length between flanges), 27 cms.

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Volume of iron in core = 27 × 25,000 = 675,000 cu. cms.

Weight armature iron = 675 × 7·8 = 5,250 kgs.

The cross section of the magnetic circuit in the armature core below the slots is shown in Fig. 15, and is seen to be

$$2 \times 42 \times 27 = 2270 = \text{sq. cms.}$$

for it must be remembered that after crossing the gap and entering the armature core, the flux M branches and flows in opposite directions along two paths toward the neighbouring poles on either side, as indicated in Fig. 16.

The flux density in the armature core below the teeth is therefore

$$\frac{21{,}800{,}000}{2270} = 9600 \text{ c.g.s. lines}$$

$$= 9{\cdot}6 \text{ kilolines.}$$

Cycles per second × kilolines density below slots = $\frac{6{\cdot}67 \times 9{\cdot}6}{100} = 0{\cdot}64$.

From Fig. 14, the corresponding rate of expenditure of energy in hysteresis and eddy currents = 1·7 watts per kilogram of armature iron.

Total core loss = 5250 × 1·7 = 8900 watts.

The next step will be to ascertain the "watts per square decimeter of external cylindrical surface of the armature." This could not be done in the preceding article, as we had merely determined the armature copper component of the total loss. Now, however, we have the remaining component of the total armature loss. Here again the precise method of carrying out the end connections would affect the length of the winding from end to end, and it is useful to take an average expression for this. A good approximation to the overall length, L, may be obtained by increasing the gross length λ_g between flanges by 0·7 τ, thus

$$L = \lambda_g + 0{\cdot}7\,\tau.$$

In the case of this 400 kilowatt dynamo, $\lambda_g = 40$ and $\tau = 91$, and the overall length of the armature (*i.e.*, over armature end connections) may be estimated as

$$L = 40 + 0{\cdot}7 \times 91 = 104 \text{ cms.}$$

Let D equal the armature diameter, then radiating surface = π D L = $\pi \times 230 \times 104$ = 75,000 sq. cms. = 750 sq. dms.

Armature copper loss = 13,100 watts
Iron loss . . . = 8,900 watts

Total armature loss = 22,000 watts

Watts per square decimeter of cylindrical radiating surface of armature (hereafter to be referred to for brevity's sake as "armature watts per square decimeter")

$$= \frac{22{,}000}{750} = 29{\cdot}4.$$

This is a very conservative value, and with the ventilation provided, would not, at this speed, lead to over 30° Cent. thermometrically determined rise, on continuous operation, at full rated load.

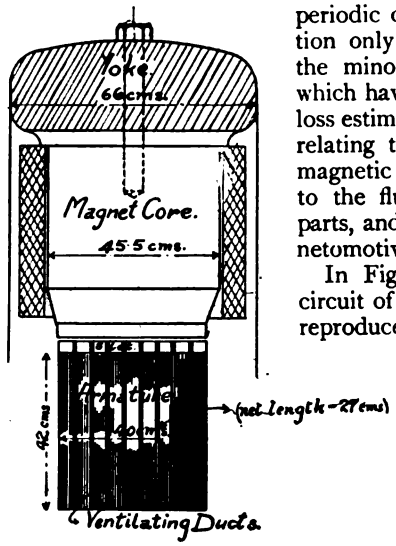

FIG. 15.—DIAGRAMMATIC SKETCH OF MAGNETIC CIRCUIT OF 400 K.W. DYNAMO, SHOWING THE CROSS SECTION OF ARMATURE AND YOKE.

As the magnetic flux undergoes periodic changes in value and direction only in the armature (aside from the minor losses in the pole face, which have been included in the core loss estimate), the remaining questions relating to the proportioning of the magnetic circuit have reference mainly to the flux densities in the various parts, and to the corresponding magnetomotive forces required.

In Figs. 15 and 16 the magnetic circuit of the 400 kilowatt dynamo is reproduced, and the cross sections and lengths of the different parts are indicated against them.

In the first instance, the magnetomotive force must be estimated on the assumption of zero armature interference. But the corresponding flux entering the armature will be taken at 21·8 megalines, corresponding to the internal potential of 574 volts. This internal voltage, at full load, gives but 550 terminal volts.

Although one naturally thinks of the region enclosed by the magnet windings as being the seat of generation of the magnetomotive force, it is in the armature winding that it becomes manifest, and the order of procedure is based upon this consideration.

We have already determined the density

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below the teeth as being 9,600 lines per square centimeter. The corresponding magnetomotive force is found from the standard curve for sheet-iron shown in Fig. 17 to be 4 ampere-turns per centimeter. The length per pole is 42 centimeters. Hence the magnetomotive force for the armature core is $4 \times 42 = 88$ ampere-turns per field spool.

THE TOOTH DENSITY.

The determination of the tooth density and the corresponding magnetomotive force is based upon a series of approximations which are justified on the score of brevity, and of the sufficient commercial accuracy attained by their means.

The maximum tooth density alone, *i.e.*, the density at the roots of the teeth, is estimated.

The polar pitch, τ, of the 400 kilowatt dynamo is equal to 91 centimeters. The pole arc (see Fig. 16) is equal to 61 centimeters.

$\therefore$ Pole arc = 67 per cent. of polar pitch.

The armature has 264 teeth, or

$$\frac{264}{8} = 33 \text{ teeth per pole.}$$

Teeth lying directly below the mean pole arc

$$= 0{\cdot}67 \times 33 = 22{\cdot}2.$$

But the lines do not cross radially from the pole face to the armature surface, but spread into teeth lying to both sides of those directly below the pole arc. For this machine the "percentage allowed for spread" may be taken as 10 per cent.

Total number of flux-carrying teeth per pole

$$= 1{\cdot}10 \times 22{\cdot}2 = 24{\cdot}4.$$

Armature diameter = 230 cms.

$2 \times$ depth slot $= 2 \times 3{\cdot}3 = 6{\cdot}6$ cms.

Diameter at bottom of slots = 223 cms.

Circumference at bottom of slots $= 223\pi$ = 700 cms.

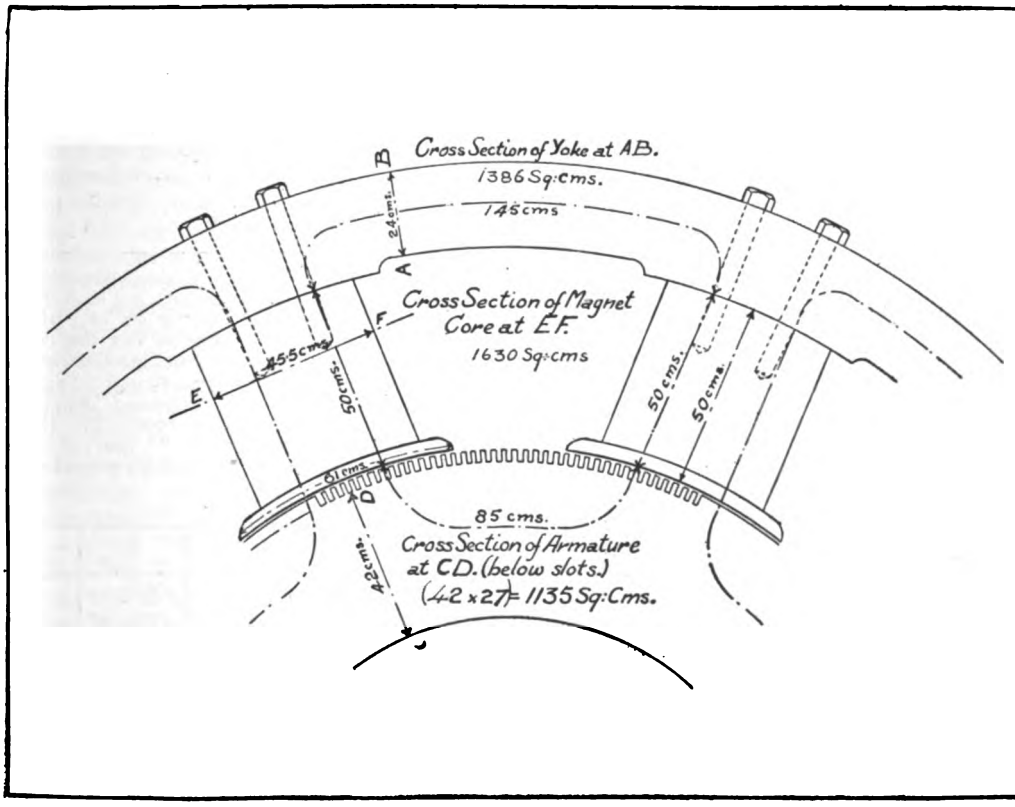

FIG. 16.—DIAGRAMMATIC SKETCH OF MAGNETIC CIRCUIT OF 400-K.W. DYNAMO, SHOWING THE VARIOUS LENGTHS AND CROSS SECTIONS.

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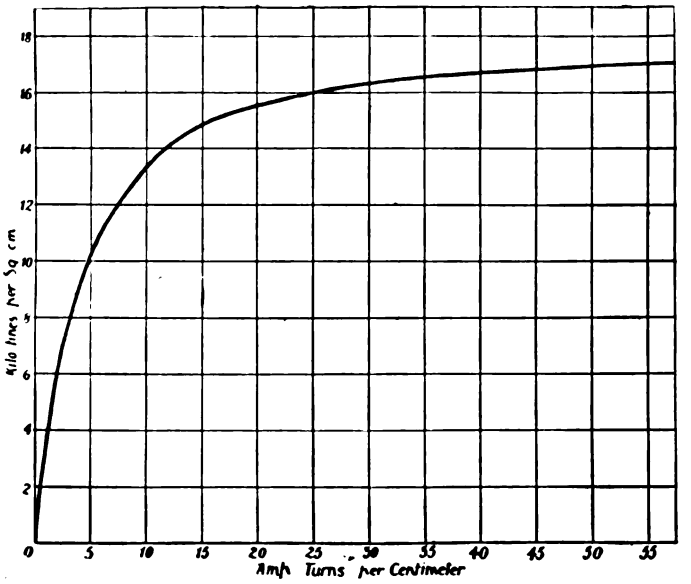

FIG. 17.—STANDARD MAGNETISATION CURVE FOR SHEET-IRON.

"Tooth pitch" at bottom of slots (*i.e.*, width of tooth + slot)

$$= \frac{700}{264} = 2{\cdot}66 \text{ cms.}$$

Width of slot . . . = 1·23 cms.

∴ Width of tooth at root = 1·43 cms.

Width of 24·4 teeth at roots
= 24·4 × 1·43 = 34·8 cms.

λ_n = 27·0 cms.

Cross section of magnetic circuit at roots of teeth
= 34·8 × 27·0 = 940 sq. cms.

"Apparent" density at roots teeth $= \frac{21{,}800{,}000}{940}$
= 23,200 c.g.s. lines.

This is designated the "apparent" tooth density, since the permeability of the very best sheet-iron, at these high densities, is not so very many times greater than unity (*i.e.*, than air and copper and insulations and other diamagnetic substances), and therefore a considerable percentage of the total flux does not flow down the teeth, as has been assumed in calculating the "apparent" density, but follows the parallel path of higher magnetic reluctance offered by the slots, the ventilating ducts, and the insulation between adjacent armature laminations. Calculations on this precise basis are much more difficult than the calculation of branching electric conducting circuits of different resistances, because the ratio of the reluctances of the parallel magnetic circuits varies greatly with the flux density, whereas the resistances of the electric circuits are of course constant, and independent of the current strength. Nevertheless such a method has been developed, making certain assumptions in accordance with customary dynamo proportions.*

* This method was devised by the writer in 1892, and he at that time incorporated the results in the set of curves here reproduced in Fig. 18. Except that they are in metric measure, these curves are identical with those published ten years later in 1902, in Fig. 7 on p. 32 of Dr. Thompson's "Dynamo Design." They had already been published in 1900 in Fig. 127, on p. 126 of "Electric Generators." The assumptions are crude, nevertheless the now fairly general use

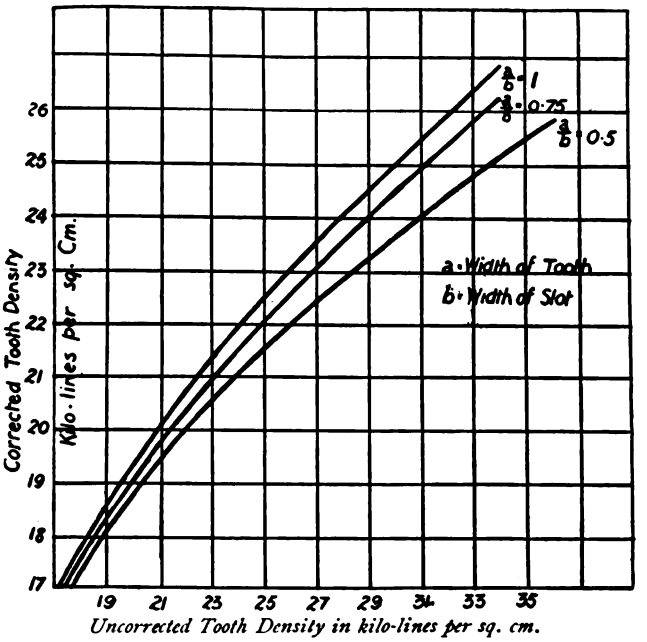
a/b = 1
a/b = 0·75
a/b = 0·5
a = Width of Tooth
b = Width of Slot
Corrected Tooth Density
Kilo lines per sq. Cm.
Uncorrected Tooth Density in kilo-lines per sq. cm.

FIG. 18.—CURVES FOR ESTIMATING THE CORRECTED TOOTH DENSITY.

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The curves resulting from these considerations and commercially employed for correcting the "apparent" tooth-density, are given in Fig. 18. From these curves it is seen that the ratio of width of slot to width of tooth (*i.e.*, the ratio $\frac{a}{b}$ of the curves), must be obtained. This, in the case under consideration, is:—

$$\frac{a}{b} = \frac{1\cdot43}{1\cdot23} = 1\cdot16.$$

Knowing this ratio, we find from the curves of Fig. 18, that the "true" tooth density corresponding to an "apparent" density of 23,000 lines, is 21,800 lines.

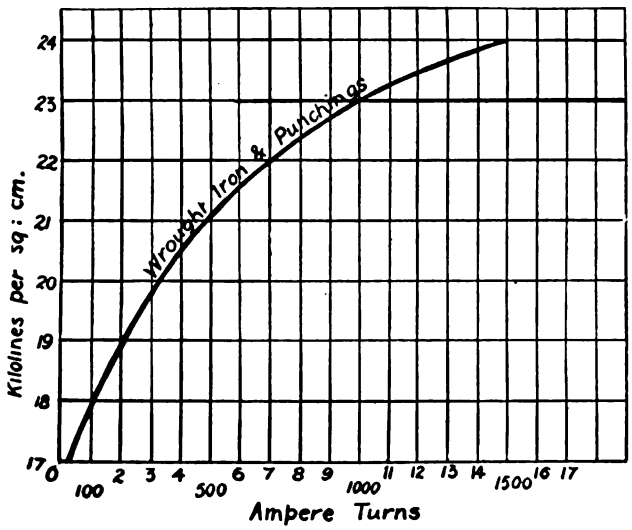

FIG. 19.—SATURATION CURVE FOR HIGH DENSITIES.

In Fig. 19 is given a curve showing the magnetomotive force (expressed in ampere-turns per centimeter), required at high densities in armature laminations. The curve shows that 640 ampere-turns per centimeter are required at a "true" density of 21·8 kilolines per square centimeter.

In Fig. 20 this curve is transformed to show the permeability μ in terms of the density per square centimeter, B. μ is a term expressing the ratio of the lines present in a given magnetic substance, to the lines that the same magnetomotive force would set up in air. We thus see that in the case under consideration, where the "true" density is 21,800 lines, the permeability of the iron is only 42 times greater than the permeability of air, copper, or other diamagnetic material. At low densities, the best sheet-irons often have values for μ well above 3000.

As the length of the tooth is 3·3 centimeters, a final result of

3·3 × 640 = 2100 ampere-turns for the magnetomotive force per spool, required for the teeth, is obtained.

The "percentage allowance for spread," which in the above example was taken as 10 per cent., is a factor of which no exact estimate can be made. And yet it greatly affects the value obtained for the tooth ampere-turns. This may be illustrated by the case in hand. Had we, instead of 10 per cent., allowed 15

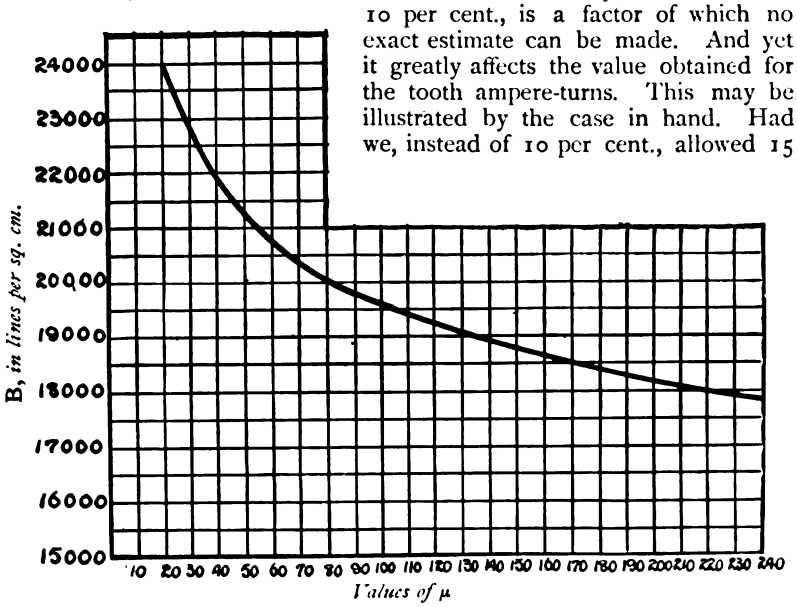

FIG. 20.—PERMEABILITY CURVE FOR SHEET-IRON AT HIGH DENSITIES.

of this method twelve years after it was first employed, and notwithstanding the appearance of numerous alternative methods in the meantime, justifies the belief that it is probably one of the most useful methods for approximate practical calculations, where economy in time is an object.

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per cent., the "apparent" density would have been

$$\frac{1\cdot10}{1\cdot15} \times 23{,}200 = 22{,}200 \text{ lines.}$$

"True" density (from Fig. 18) = 21,100 lines.

Ampere-turns per centimeter (from Fig. 19) = 500.

Ampere-turns per field spool required for teeth = $3\cdot3 \times 500 = 1650$,

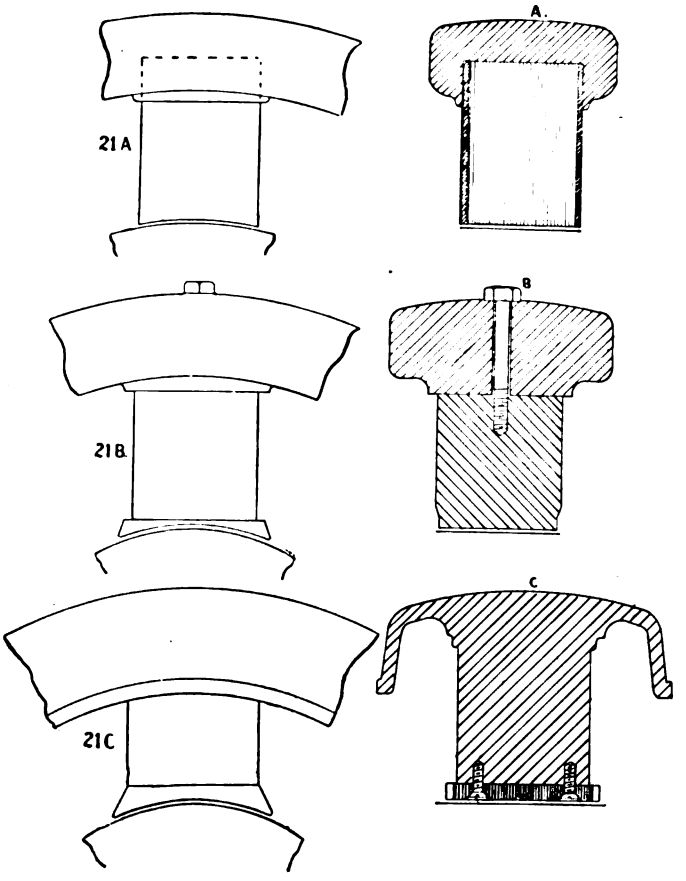

FIG. 21.—DIFFERENT TYPES OF MAGNET CORE.

instead of 2100 obtained by the use of a 10 per cent. allowance. This is a reduction of 21 per cent., corresponding to an increase of only 5 per cent. in the assumed "spreading factor."

One can only decide which value to employ, by the exercise of judgment and in the light of experience.

In Figs. 21A, 21B, and 21C, are shown three types of magnet core, all of which are extensively used and with good results. The design in Fig. 21A employs a laminated core of rectangular cross section and without polar extensions. The magnet core is worked at a very low magnetic density, otherwise an uneconomically high density in air gap and teeth would result. The design in Fig. 21B is similar to that of the 400 kilowatts generator under consideration; a steel core of circular cross-section and run at a very high magnetic density is cast in one piece with an extended pole shoe. In the design in Fig. 21C the magnet cores and the magnet yoke are in one steel casting. The pole shoes are of laminated iron and secured by bolts to the magnet core. In these last two constructions, as compared with the first one, the magnetic flux is more or less throttled in its path to the extreme pole tips. In these two types of design, without and with polar extensions respectively (compare Fig. 21A with Figs. 21B and 21C), 20 per cent. and 10 per cent. allowance for spread should be made in estimating the tooth density. Should a cast iron pole shoe be used with a cast steel magnet core, the spreading would be still further decreased, owing to the lower permeability of cast iron. The shape of the polar extensions should also come into consideration. As a matter of fact, from 10 per cent. to 20 per cent. would be suitable for most cases, the smaller value being the safer, except where there is ample reason, as in Fig. 21A, for employing the higher value.

It will also have been observed that the density at the root of the teeth is employed, although the teeth flare to such an extent that the mean density is very much less, and the mean magnetomotive force is less in a still far greater proportion. This has led some designers to propose and employ other methods in which an attempt is made to introduce the true value for the total tooth length.

(To be continued.)

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THE SCIENCE OF THE ENGINEERING WORKSHOP.

THE following syllabus of a course of instruction for engineering students is being carried out at the Leicester Municipal Technical Schools, which, through the enterprise and generosity of the local engineers, have been equipped with suitable appliances. The syllabus is the work of Mr. W. Taylor and the Advisory Committee of Engineers to the Institution.

This course of study has three divisions, dealing respectively with Materials, Processes, and Tools.

The object of the study of materials is to familiarise students with the appearance, structure, and properties of materials commonly used in engineering, from the point of view not of the designer, who considers chiefly their strength and permanence, but from that of the mechanic who shapes such materials by straining them beyond their elastic limits.

When the character and properties of materials are known, the processes by which they may be shaped will be considered, and at the same time tools and methods of carrying out such processes will be seen and used by the students.

This course is not intended to impart skill in handicraft, which can only be acquired by extended practical experience, and not in a school.

MATERIALS.

Common workshop materials :—Cast and malleable cast iron, wrought iron and steel, copper and brasses, zinc, lead, and wood. Brief study of the sources and methods of production of metals in the form of plates and bars.

Specimens of ore, pig, cast, and rolled metals.

The character of the Bessemer, open hearth, and crucible processes of steel making. Case-hardening iron.

Fractures of different metals. The corresponding crystalline structure of polished specimens exhibited in the microscope.

Malleability, ductility, hardness. The hardening effect of pressure. The superficial effect of hammering.

The various effects of thermal treatment upon different metals.

SPECIAL STUDY OF TOOL STEEL.

Appearance of fractures of steels containing various percentages of carbon, and of air hardening steels.

Corresponding appearances in the microscope of etched and polished specimens.

The plastic, granular, and molten states of steel.

Cooling curves. Visible recalescence. The pyrometer.

Effect of different heat treatments on fracture and crystalline structure.

Examination with the microscope of polished and etched specimens of the same steel with various thermal treatments.

Measurement of hardness of hardened tool steel. How its hardness varies with temperature. Modern high speed steel.

Internal strains set up when a mass of steel is heated or cooled. Analogy to the cooling of the earth and earthquakes. Cracking and warping, and their causes. Permanent expansion or contraction.

Heating steel for hardening. Objections to open fires and blow pipes. The lead bath. The muffle. Surface protection.

Practical use of the pyrometer, and other heat gauges.

Cooling steel for hardening. Representative cooling media :—Air, oil, water, salt water, and mercury. Their modes of action and applications to different uses.

Importance of equal and simultaneous cooling of the mass.

Quenching symmetrical and unsymmetrical pieces, and means for reducing local shrinkage strains.

Subsequent tempering, and the practical measurement of temperature for this purpose.

Colours of oxidation. Use of lead and oil baths, and the flaring of oil.

Cooling after tempering. Repeated tempering. Seasoning steel.

Annealing tool steel. Water annealing.

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WORKSHOP PROCESSES FOR SHAPING MATERIALS.

Processes for Shaping by Pressure or Drawing, without Heat.

The plasticity of metals at ordinary temperatures. Malleability and ductility.

Microscopic study of the structural changes and flow of metal which occur when a bar is bent.

Examples of coined work, collapsible tubes, gold leaf, sheet lead bossing, pressed steel cycle parts, cartridge shells, and drawn tubes and rods.

Limitations of the process. Hardening of metals under treatment. Cause and avoidance of rupture. Permanent internal strains produced by pressure.

Effect of time on the plasticity of metals. Likeness to the behaviour of pitch.

Exercises: Rolling metal strips. Coining soft metals. Rivetting. Knurling. Centre and figure punching. Burnishing. Sizing holes with plain drifts. Planishing metal sheets to remove buckles. Drawing wire. Drawing cups in a press. Spinning. Bossing sheet lead. Bending and straightening wire.

Visits to works where operations of shaping metals cold by pressure may be seen.

Processes for Shaping by Pressure aided by Heat.

How the plastic properties of metals vary with temperature. Tests under heat in the testing machine.

Distinction between metals and alloys. Reducing brass to powder.

Hot rolling of metals into rods and sheets. The influence of time. The steam hammer and hydraulic forging press.

Visits to smithies to see various forgings.

Exercises:—Hot rolling of metal strips. Upsetting and making rivets. Hot rivetting. Drawing out and bending smith's work.

The plastic state of alloys. Squirting "compo" pipes and bullet rod.

"Extrusion of metals." Specimens of pipes, cable sheathing, and extruded metals.

Processes of Shaping by Fusion and Casting.

Visit to a foundry, and explanation of foundry methods.

Exercises:—Preparation of sand moulds from:—

(*a*) A semi-cylindrical pattern.
(*b*) A second side added to pattern by dowels.
(*c*) The alternative use of match plate.
(*d*) A solid pattern with irregular parting.
(*e*) Moulding in three part box.
(*f*) Cylindrical core.
(*g*) Irregular core for hollow casting.

Core supports. Gates and vents. Porosity of moulds and cores.

Casting by students in their own moulds with white metal.

Shrinkage in cooling. Feeding. Draw and Blow holes.

Inevitable shrinkage strains. Specimens of castings fractured in cooling.

Second visit to foundry.

Force in casting, supplementary to force of gravity.

Specimens of cast types and "finished castings."

Processes of Shaping by Addition and Surface Fusion.

General principles. Importance of cleanliness. The use and action of fluxes, as:—Tallow, resin, zinc chloride, borax, sand.

Exercises:—Soft soldering sheet metal with copper bit. Soft soldering heavier masses with the blow-pipe. Making plumbers' wiped joints. Soft soldering cast iron. Silver-soldering wire, brazing a cycle joint, a brass tube, and a copper ball. Brazing cast iron.

Welding iron and mild steel and higher carbon steel.

Processes of Shaping Materials by Cutting.

The essential nature of cutting action.

Difference between cutting and splitting illustrated in cutting wood along the grain. Difference between cutting and shearing illustrated by the wood saw or parting tool.

Study of the strains produced by a cutting tool in a homogeneous material, as in paring the edge of sheet lead with a chisel, or on a large scale with tempered clay and a wooden chisel.

The effect of lubrication.

Complete penetration and severance of the material by the cutting edge, essential to perfect cutting action and the production of a smooth surface. Impossibility of producing smooth surfaces by shearing. Effect of bluntness of the tool.

Study in the lathe, and with the microscope, of the mode of separation of chips of various

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thickness from cast iron, tool steel, mild steel, and copper, and of the effect thereon of varying cutting angles. Top and bottom rake. Effective bottom rake dependent on rate of feed. Bending chips of straight and of curved section.

Characteristics of roughing and finishing tools, and the avoidance of shearing action in the latter.

The blunting of tools by abrasion, and by heating. High speed steels. Cutting speeds and feeds. Chattering and its causes. Accuracy of cutting action.

Characteristic features of machines for operating cutting tools, as the lathe, shaper, milling and drilling machines.

Study of the characteristics and action of turning and planing tools for various purposes, of milling cutters and files, drills, reamers, taps, and dies.

Exercises:—Sharpening tools.

Lathe Work. Chucks and chucking. Holding without distortion. Centres and centering. Carriers. Live and dead centres. Steadies. Adjusting the lathe. Turning cylindrical pieces. Cones. Facing. Boring. Reaming. Screw-cutting. Hand-turning. Turning irregular forms.

Shaper Work. Holding the work. Holding without distortion. Three point bearings. Shaping a true plane. Two parallel planes. Planes at various angles. Cylindrical and irregular forms.

Milling. Milling plane surfaces with spiral mills and end mills. Milling with gang mills. Milling irregular forms. Milling slots. Milling with hand and power feeds.

Drilling. Use of common flat drills, twist, and straight fluted drills. Hand and power feeds. Drilling jigs. Counterbores and facing cutters. Machine and hand reamers.

Tapping. Tapping by hand and machine. Sharpening taps.

Abrasive Processes.

Study under the microscope of an abrasive particle scratching the surface of various materials at low speeds. Effects of plasticity and hardness. The effect of high velocities and heating of the work.

Common abrasives:—Gritstone, oilstone, sand, powdered glass, emery, carborundum, diamond.

Methods of supporting abrasives in glass and emery paper, in polishing wheels, in vitrified emery and carborundum wheels.

Shellac wheels and the use of metal laps.

Study of the breaking down action of emery wheels, and the relation of grades and grains to velocity, and to the material ground.

Grinding to remove material. Grinding for a finish. Accuracy of grinding.

The nature of polishing action studied microscopically. Polishing steel and brass, &c.

Exercises:—Rough grinding a soft steel shaft. Finishing. Grinding hardened steel and cast iron. Surface grinding. Sharpening cutters. Polishing steel and brass.

The Hammer.

Uses and abuses of the hammer. Effects of hard steel hammers. Relation of size of hammer to purpose. The plastic lead hammer. The elastic mallet.

Measuring and Gauging.

Accuracy of form and finish. Economic value of accuracy. Interchangeability. Degrees of accuracy. Standards of length. Sub-division of standards. Conveniences of binary and decimal divisions. Workshop standards. Principles to be observed in using calipers. Personal equation. Micrometers. Verniers. Systematic gauging. Limit gauges. Shrink fits, driving fits, running fits.

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THE PHOTOGRAPHIC IMAGE, IN THEORY AND PRACTICE.

PART I.

By EDGAR SENIOR.

WHEN, in 1556, the alchemists observed the darkening action of the sun's rays upon horn silver, they little thought of the great importance this discovery was destined to attain. These empirical philosophers had among them men of superior gifts, and the careful experiments conducted by them, in the endeavour to transform the baser metals into gold, or to distil the *elixir vitæ*, produced results which were afterwards to become the guiding light in modern investigations. The nature of the darkening, however, appears to have been looked upon as a species of transmutation of metals; and at a later period—in the seventeenth century—Glauber and Robert Boyle speak of the discoloration of silver compounds, although they do not seem to have suspected the darkening to be due to the action of light.

Early Investigations

The first to suggest the action of light as the cause of the discoloration was most probably J. H. Schulze, in 1727. He found that chalk which had been treated with a solution of silver in nitric acid became discoloured on the surface exposed to light, and he proved the effect was not due to heat. In 1777 Scheele, the Swedish chemist, investigated the matter, and found that distilled water, "under which carefully prepared silver chloride had been exposed to light," contained a dissolved substance which, when a solution of silver nitrate is added, gives once again silver chloride; and that on the application of ammonia to the darkened chloride a residue of metallic silver remains behind. These facts, then, prove that the change brought about by light is of a chemical nature, and that light acts in a reducing manner.

Chemical Nature of Photographic Action

A modified form of this experiment may be performed by exposing carefully washed silver chloride or bromide to light in the bottom of a test tube, in the upper part of which hangs a strip of paper prepared with starch and potassium iodide: the liberation of chlorine or bromine will be indicated by the starch-paper turning blue. A strip from a gelatino-bromide dry plate can be used and the same reaction obtained.

Both the inorganic and organic salts of silver undergo more or less decomposition by the action of light, although in some cases it is necessary that some oxidizable substance be present. Silver nitrate, pure or in aqueous solution, is insensitive to light in the absence of organic matter (Eder). In a paper read before the Royal Institution in 1802, Thomas Wedgwood described some experiments undertaken in collaboration with Sir Humphrey Davy, for the production of images by the agency of light upon paper and white leather which had been prepared with a coating of silver nitrate; and it is recorded that silver chloride was also tried and found to be more readily acted upon by light. Since only such objects as could be laid directly in contact with the prepared surface, or could be made to cast their own shadows, were available for use; and since the results could only be examined in feeble light, "as at that time no method for fixing the images was known," the experiments were only interesting scientifically. About this period a new method of investigation by means of the spectroscope was being made use of, and in 1801 Ritter of Jena, after repeating the experiments of Scheele, discovered that silver chloride is rapidly darkened in that portion of the spectrum which lies beyond the extreme violet. He also noticed that the red rays exercise a bleaching action on the darkened chloride, and finally restore it to its original colour.

Action of Ultra-violet Light

It is only natural that the question should suggest itself: What is the nature of the darkened substance resulting from the exposure of silver chloride to light? The theory that the change produced is merely a physical one may be at once dismissed, since it is proved that the chloride loses chlorine; further, if the increased vibrations produced by light were alone responsible, it would follow that the enhanced vibrations can be maintained for at least a year. Now, since we find from experiment that

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chlorine is evolved, one of two things must take place—either the total liberation of the halogen from the silver salt, or its partial liberation. Which of the two occurs? That it is not metallic silver which is left appears to be borne out by the fact that the darkening will take place under dilute, or even strong nitric acid, although less rapidly in the latter case.

Formation of Sub-salts

The question naturally arises, Can such a body as a sub-chloride be formed? This view appears to have been put forward by Fischer in 1814, and again in 1834 by Wesylar. Silver, however, is usually considered to be a monatomic element, and white silver chloride the only compound formed with chlorine. The analogy, however, between the silver and copper salts renders it probable that silver is a dyad.

Comparison has also been made between its chloride and those of copper and mercury in the cuprous and mercurous state, but analogy fails if an attempt be made to compare the darkened chloride with these bodies. The darkened body may contain oxygen, the requirement of this element for the darkening being mentioned by Robert Hunt:* Dr. Hodgkinson has endeavoured to prove the existence of a body of the nature of an oxychloride, probably having the composition $Ag._4OCl_2$, comparable to the substance formed by light on white chloride of copper, which becomes brown under its influence, due, it is believed, to the formation of an oxychloride.

Action of Moisture and Oxygen

But experiments are not wanting to show that moisture or oxygen are not essential, as the dry chloride will darken under dry benzine, and in a vacuum, if some substance be present that will combine with chlorine, such as a particle of mercury, etc. The darkening will also take place if the dried chloride is sealed up in a tube of hydrogen, but not if exposed to light in a vacuum (Sir W. de W. Abney, "Recent Advances in Photography," 1882). In 1839 Wöhler found that if argentic citrate be heated at 100° C. in a current of hydrogen, half the acid is liberated and a compound sparingly soluble in water is produced, giving a brown solution which, on the addition of potassium hydrate, gives a precipitate of silver suboxide; it also appears to be formed by the action of hydrogen peroxide on metallic silver. Argentous oxide mixed with metallic silver is also obtained by boiling triargentic arsenite with a strong solution of caustic soda:—

$$2Ag_3AsO_3 + 6NaOH = Ag_4O + Ag_2 + 2Na_3AsO_4 + 3H_2O$$

Argentous salts are also said to be formed by passing hydrogen into ammoniacal solutions of silver salts.

The bearing that these experiments have is readily seen. Admitting the existence of a sub-oxide, we have at once a key to the problem, as from it a sub-chloride should be obtainable. Indeed, Wöhler has described a means of obtaining the same by the action of hydrochloric acid, or a solution of common salt, on the sub-oxide:—

$$Ag_4O + 2HCl = 2Ag_2Cl + H_2O$$

and

$$Ag_4O + 2NaCl + H_2O = 2Ag_2Cl + 2NaOH$$

The chemically prepared argentous salt appears to behave in the same manner as the light-produced compound, in being unacted upon by nitric acid, but decomposed by ammonia, leaving a residue of metallic silver. Here, then, is strong proof in favour of the two being alike in nature.

An appropriate question now to ask would be: When a short exposure to light is given, which produces no apparent result, is the nature of the change the same as when visible darkening occurs? If the theory be admitted for the formation of the visible image, it seems hardly reasonable to deny a similar formation to the invisible one, since it is only a difference in the amount of matter changed. Sir William Abney has found that the spectra produced are the same, both as regards their limits of sensitiveness and relative sensitiveness, with either a short exposure to light and subsequent development, or with a printed image obtained by prolonged exposure. When the developed and printed images on silver chloride are treated with certain reagents their behaviour is the same (Eder). Pretty strong nitric acid has no effect on either. Hydrochloric acid destroys both. Sulphuric acid slightly weakens both, and similar results are produced with other substances. The theory to which most authorities appear to subscribe is—that the visible and invisible images are of the same composition: that the action of light is of a reducing nature; and that the reduction product is a sub-salt, whether it be a chloride, bromide, or an iodide of silver that has been acted upon, although in the latter case the change takes place with extreme difficulty,

Reducing Action of Light

* "Researches on Light," 2nd edition, 1854.

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unless some body be present to act the part of an halogen absorbent.

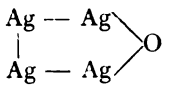
The changes may be represented chemically thus—

$$2Ag_2Cl_2 = 2AgCl + Cl_2$$

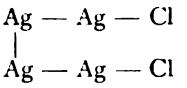
and $$2Ag_2Br_2 = 2Ag_2Br + Br_2.$$

Although such a formula as Ag_2Br is difficult to reconcile with the theory that silver is a monad, no violence is done to generally accepted chemical laws if we regard it as of dyad valency, as the following graphic formulæ show:—

Silver suboxide.



Silver subchloride.



Although we have been considering light as acting in a reducing manner, cases are not wanting in which it appears to act by oxidation. As an example we may mention the process devised by M. Niepce of Châlons in 1814. The material he employed was asphaltum and resin. If a thin film of a solution of these in alcohol, ether, or some essential oils be spread upon a metal plate and allowed to dry away from light, and then exposed to daylight underneath some object placed in contact with it, the parts so exposed become changed, so that on the application of the solvent only those parts that have been protected dissolve. This insolubility was believed to be due entirely to oxidation, but according to some researches by Kayser ("Photo Cor.," Sept. 1879), the insolubility is not only caused by that, but also to polymerisation (alteration in molecular condition). Asphaltum, although very slowly changed by light, appears to be sensitive throughout the entire visible spectrum, and is said to have its sensitiveness increased by the addition of sulphur.

Oxidising Action of Light

In January, 1839, was announced to the world the first process of any importance by which images could be formed by the action of light on a salt of silver. It seems likely that Daguerre, from whom the process takes its name, conceived the idea from an experiment of Niepce's, with whom he was in partnership. The latter having produced images in asphaltum on silver plates, the application of the solvent left a brown image on a bright metallic ground (a negative). In order to produce a proper effect, iodine was applied to the bare metal, and the bitumen subsequently removed. The action of light on the portions of the plate consisting of iodide of silver may have thus given the first idea of the process. In any case the method consisted in subjecting a very highly polished silvered copper plate to the action of iodine vapour until the surface had assumed a uniform golden colour, the compound formed consisting of silver iodide, and represented chemically as follows:

The Daguerreotype Process

$$2Ag + 2I = Ag_2I_2.$$

According to what has been previously stated, on exposing such a prepared surface to light, the silver iodide would be decomposed with difficulty. But the conditions here are different, as there would be an amount of metallic silver that had not been converted into iodide, and this would aid the light in its reducing action. In accordance with theory, there would be formed a sub-iodide of silver according to the equation—

$$2Ag_2I_2 = 2AG_2I + I_2,$$

the quantity depending upon the duration of the light's action. On exposing these prepared plates in a camera, apparently no effect was produced, but by a fortunate accident Daguerre found that the vapour of mercury was able to develop the invisible or photographic image, the mercury attaching itself to those parts altered by light.

It might be asked, why is there this discriminating action? If it is remembered that mercury has the property of forming an amalgam with both silver and gold, and that in all probability we have an unsaturated silver compound present, a possible explanation is found. In any case we know that after the removal of the unaltered silver salt, "which was at first accomplished by means of a strong solution of salt, and later by hypo," an image is left consisting of various quantities of condensed mercury vapour on a highly polished silver ground. Thus, with slight modifications, such as treating the iodised plate with bromine to increase its sensitiveness, the daguerreotype process remained, and constituted the first method of any importance for producing camera images.

Use of Mercury Vapour

While Daguerre was at work in France, Fox Talbot had been occupied in this country with experiments aiming at the production of images with silver salts spread upon paper, and in January, 1839, he read a paper before the Royal Society on what was termed "Photogenic Drawing." He appears to have taken writing paper and dipped it into a weak solution of common

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salt, and after drying it, to have applied to one surface a solution of silver nitrate, by which means silver chloride was obtained with a slight excess of the nitrate. On laying such objects as leaves, lace, etc., on this prepared paper and exposing to light, a negative image was obtained. On fixing these images with strong solutions of chlorides or bromides, and placing them over similarly prepared papers and allowing light to act through them, a positive image was obtained. The great advantage of this method consisted in the number of copies which could be obtained. Talbot appears to have tried this silver chloride paper for the production of camera images, but finding the action very slow and the images weak, he was led to experiment with iodide of silver. For this purpose writing paper was taken and coated with a solution of silver nitrate, and when dry, dipped into a solution of potassium iodide. When dry this paper was found to be scarcely sensitive to light. When required for use it was washed over with a solution of silver nitrate. Such a paper was found sufficiently sensitive for obtaining camera images. The Rev. J. B. Reade, in experimenting with this process, found that a paper which had been washed over with a solution of gallic acid, and which had only received a short exposure in the camera, was fully developed after remaining some hours in the dark. From this arose the idea of development of what was termed the *latent image*. Fox Talbot employed this method in the process which he patented in 1841 under the name of *calotype*, the iodised paper being washed over with a mixture of silver nitrate, acetic acid, and gallic acid, and exposed damp in the camera. With short exposure the image is invisible, but will gradually develop if kept in the dark, or may be developed at once with gallo-nitrate of silver, ("silver nitrate, gallic acid, and acetic acid.") The pictures, being washed, were fixed with a strong solution of common salt or with potassium bromide.

The Latent Image

The use of glass as a support for the sensitive salt appears to be due to Sir John Herschell. He formed a film of precipitated silver chloride upon a glass plate by mixing together a very dilute solution of salt and silver nitrate, such that a slightly milky liquid was formed. This was allowed to slowly deposit on the plate placed at the bottom of a deep vessel. The liquid being carefully syphoned off and the plate dried, a fine deposit of silver chloride was obtained, upon which he printed "in the camera" an image of his forty-foot telescope in 1843. The delicate nature of the operations involved in a method of this kind may be readily imagined, and a further step in advance was made when Niepce de St. Victor succeeded in using albumen as a vehicle for holding the sensitive salts. The discovery of pyroxylin, and that a solution of it in a mixture of alcohol and ether, when spread upon glass, formed as a thin transparent film on drying, suggested to M. Le Gray of Paris its possible use as a vehicle for the sensitive salts employed in photography. Scott Archer, however, was the first to carry out the idea in practice, the method being described by him in *The Chemist* at the end of the year 1851. This process, known as the collodion process, constituted one of the most important photographic discoveries. The base of the substance "pyroxyline" is a substitution product of cellulose, in which hydrogen is replaced by nitryl (NO_2). Several varieties are known, mainly distinguished by their stability and degrees of solubility in alcohol and ether, etc., the solution of the less highly nitrated compounds in these liquids forming collodion. In this process a plate of chemically-cleaned glass is coated with collodion, in which iodides and bromides of certain metals are dissolved; on the film becoming set, it is placed in a solution of silver nitrate, when, by chemical decomposition, iodide or bromide of silver is formed thus—

The First Photographic Plate

The Collodion Process

$$CdI_2 + 2AgNO_3 = 2AgI + Cd(NO_3)_2.$$

The plate is exposed in the camera directly on its removal from the nitrate bath. As there is always an excess of silver nitrate present, the light is able readily to reduce the silver iodide to a sub-salt, as the liberated iodine has a substance present with which it can enter into combination. After sufficient exposure the photographic image is developed with either an acid solution of pyrogallol or of ferrous sulphate, the image being formed by the deposition of reduced silver on those parts acted upon by light. After washing, the unaltered silver salts are removed by hypo or potassium cyanide.

Passing over the various collodion dry-plate and emulsion processes, we come to the universally employed method for obtaining photographic images in the camera—the gelatine emulsion process. To Dr. Maddox belongs the credit of preparing, in

The Gelatine Emulsion Process

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1871, the first emulsion in which silver bromide was emulsified in a solution of gelatine. Now bromide of silver assumes various physical forms which may be obtained in a variety of ways: to Mr. Bennett must be given the credit of first showing how the molecular condition which results in an emulsion of great sensitiveness, can be obtained. He showed that this change is accomplished by keeping the gelatine solution at a temperature of nearly 90° F. for a period of about a week. Colonel Wortley afterwards obtained a similar degree of sensitiveness by keeping the emulsion at a temperature of 150° F. for a few hours, and Mr. Mansfield made a still further advance by showing that the same degree of sensitiveness can be obtained by bringing the emulsion to the boiling point of water, and keeping it at this temperature for some minutes. This boiling, however, soon destroys the setting qualities of the gelatine; but Mr. W. B. Bolton found that if only a small quantity of the gelatine was employed during the process of heating, and the remainder added after the sensitivenesshad been brought about, the setting property was retained. Another method of obtaining great sensitiveness is due to Dr. Monckhoven, and results from the addition of ammonia to the silver bromide.

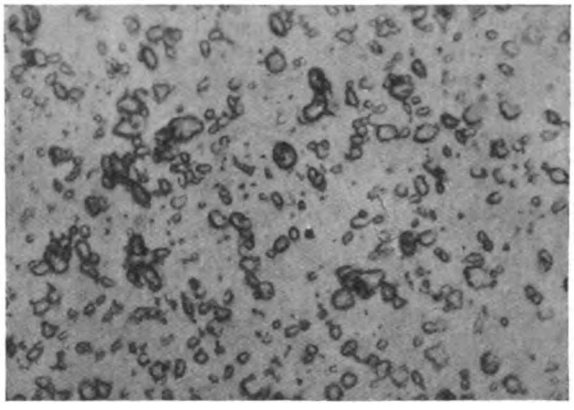

FIG. 1.—PHOTO-MICROGRAPH OF SECTION OF UNDEVELOPED GELATINE FILM.
Magnified 1,300 diameters.

An appropriate question to ask would be, What is the nature of these changes? To what may the increased sensitiveness be due? When silver bromide is first formed in an emulsion the particles are in a fine state of division, and by transmitted light appear orange or ruby, according to the thickness of the film, and measure, according to Dr. Eder, about ·0015 millimeters in diameter. After standing for a few days, or boiling for a short time, the particles of silver salt increase in size, become granular, and transmit much less red light. Dr. Stas, who carefully studied these modifications of silver bromide, describes this granular variety as the most sensitive, and as producing, in conjunction with gelatine, the most sensitive known substance for obtaining camera images.

Accretionary Process

This accretionary process is probably due to the potassium bromide and the hot gelatine exercising a solvent action on the silver bromide, and this dissolved salt being again deposited in particles of an increased size; it continues until the particles attain a diameter of ·0034 millimeters (Eder) in which state it forms the most sensitive emulsion. We thus have an illustration of how greatly the sensitiveness of silver bromide is influenced by its physical condition.

This property of potassium bromide explains the necessity for its presence in excess in the preparations of rapid emulsions. The use of ammonia in bringing about the same change also depends upon its solvent action on silver bromide. It has also been stated (Meldola) that the sensitiveness may be due to a molecular union between the silver bromide and the gelatide, producing a compound of the nature of a gelatino-bromide of silver, which would be more readily reduced than the silver bromide alone.

Microscopic Examination

An examination under the microscope when properly conducted affords interesting evidence of the different states in which silver salts exist in collodion or gelatine. In Fig. 1 is seen a photo-micrograph of an undeveloped gelatine plate of fair rapidity (184 H × 8). That the particles vary in size and form is evident. The grains are also very transparent, so much so that, but for the dark line which surrounds them, it would be difficult to obtain sufficient contrast between them and the gelatine in which they are embedded.

Bearing on this question of the molecular change undergone by the silver haloid, which results in increased sensitiveness, is the theory

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of sensitizers. It has been stated that the action of light upon iodide of silver is to reduce it to a sub-iodide, with the liberation of iodine. Such a change, however, would take place with the greatest difficulty unless some substance was present capable of combining with iodine. With chlorine and bromine the change is produced without the presence of any special substance, moisture probably being sufficient. To Dr. Vogel is due the credit of enunciating the law regarding the necessity of halogen absorbents, to which he gave the name of Sensitizers.* Carey Lea, however, was of the opinion that chemical sensitizers should be reducing bodies, and that their affinity for oxygen is of more importance than that for the halogen. To what cause the sensitiveness of a modern dry plate is due is uncertain. That it is the sensitizing action of the gelatine is doubtful, but that it is brought about by a physical modification in the nature of the silver bromide seems highly probable. The physical restraining action of the gelatine, which allows a more powerful developer to be employed, no doubt plays a part.

Sensitizers

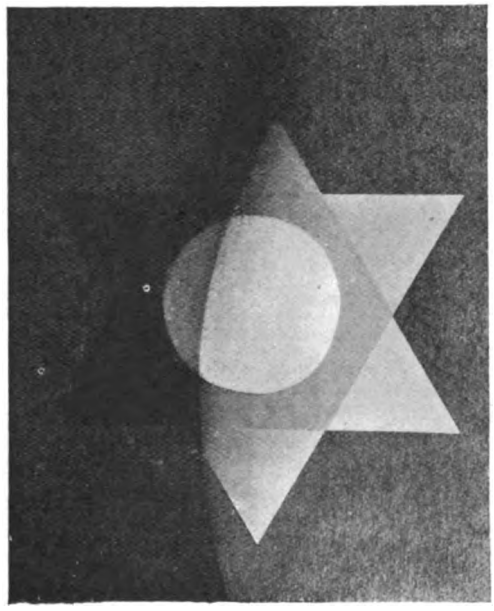

FIG. 2.—PHOTOGRAPH SHOWING THE EFFECT OF A SENSITIZER.

Sensitizers may be either organic or inorganic, and we have an example of the latter in the use of silver nitrate in the wet-plate process, the action in the presence of iodine usually being considered to be of the following nature:—

$$6I + 6AgNO_3 + 3H_2O = 5AgI + AgIO_3 + 6HNO_3.$$

A most striking example of the action of bodies of this nature is seen in the illustration (Fig. 2). This shows the result of pouring a silver nitrate solution over one-half of a photographic plate: a clear image was formed on the sensitized portion of the plate by the same exposure and development that only gave a feeble impression on the untreated portion. Such a simple experiment as this conveys more information than any written description could do.

Among other bodies which act the part of sensitizing agents may be mentioned:—Sodium sulphite, potassium nitrite, mercurous nitrate, beer, salicine, etc.; in fact, any substance which, while not taking the halogen away from the silver salt without exposure to light, is ready to absorb it when liberated.

Addition of Dye-stuffs

In 1874 Dr. Vogel made the remarkable discovery that the addition of certain dyes to an emulsion had the effect of increasing the sensitiveness of the silver salt to rays which the colouring matter absorbed. To these he gave the name of *optical sensitizers*. Their precise mode of action has never been definitely settled. The colouring matters employed are mostly of a very fugitive nature, bleaching by oxidation, and it appears most probable, as pointed out by Sir William Abney, that the oxidation of the dye precedes the reduction of the silver salt, so forming a nucleus upon which development can take place. A very strong argument in favour of this theory can be drawn from the fact that if normal collodion, stained with cyanin, is flowed over a piece of glass, and then exposed to the spectrum, and afterwards covered with a bromide emulsion: on development, a deposit is produced in the region where the cyanin absorbs light. From this it appears that the sensitizing effect is of a purely chemical nature.

Cyanin and Eosin

Of the many dyes which have been found to be effective as sensitizers, the eosin and cyanin are probably the most important. The former, and its modification erythrosin, both give precipitates with silver nitrate, which, when all the free silver nitrate has been removed by washing, can be dissolved by dilute ammonia. Gelatine plates

* *Photographic News*, 1865, p. 209.

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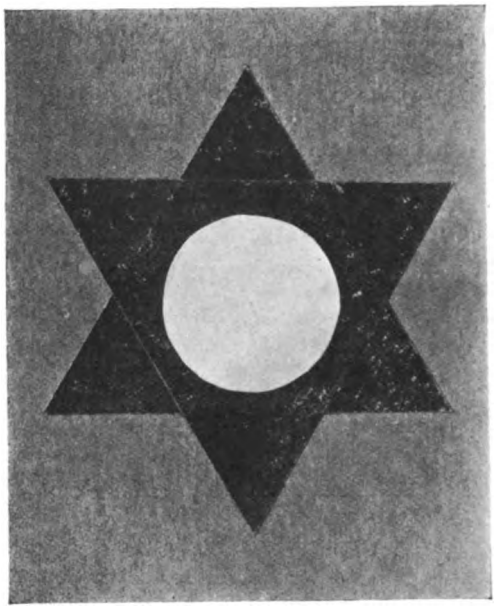
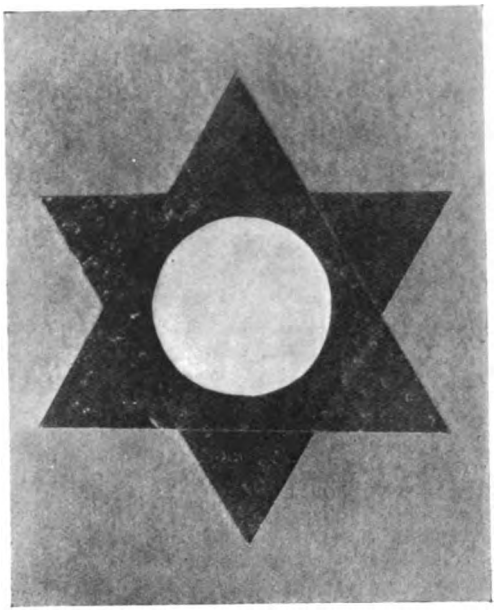
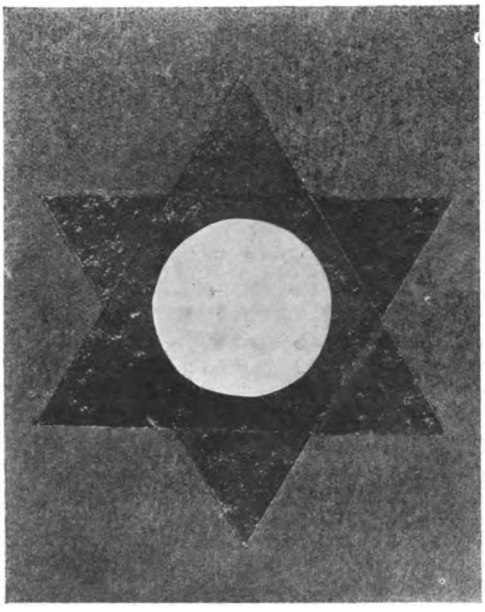


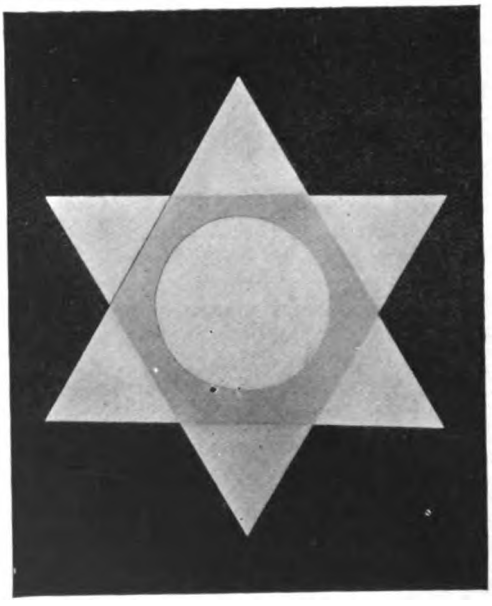
No. 1.—Print from Negative on Wet Collodion.



No. 2.—Print from Negative on Ordinary Gelatine Plate.



No. 3.—Print from Negative on Ortho Plate without Screen.



No. 4.—Print from Negative on Ortho Plate with Screen.

Fig. 3.—Prints, from Photographic Negatives, of a Light Yellow Star with White Centre on a Blue Ground.

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bathed in this solution become highly sensitive to yellow-green rays. In the case where only an aqueous solution of the dye is used, ammonia is usually employed as well, and this may aid in the formation of an organic salt of silver by its solvent action on the silver bromide.

Some of these dyes act injuriously on photographic plates, reducing their general sensitiveness, and conferring bad keeping properties upon them. Cyanin, which is useful in sensitizing for orange and orange-yellow, is one of these. If, however, the cyanin is converted by hydrochloric acid into chloro-cyanin, plates treated with this have better keeping qualities, and give clearer images generally. Two other dyes which are said to be free from the bad effects associated with the use of cyanin have lately received a good deal of attention; these are ethyl red and orthochrom T. Mention must also be made of the excellent results obtained by employing a mixture of cyanin and phosphine N, a method originally due to Mr. Gifford. These dyes are used in combination with silver salts in the preparation of photographic plates known as isochromatic or orthochromatic plates; they are used for the purpose of rendering the brightness or luminosity of colours correctly in monochrome. Taking the spectrum as our test object—if we can represent this correctly, we should also be able to properly represent any coloured object. It is found, however, that although the dyes confer sensitiveness in the regions required, blue light still acts too strongly. To modify this, a screen of an orange colour is employed, and this, when properly adjusted, can be used in the production of negatives which will represent fairly well, by the opacity of the different parts, the brightness of the spectrum in the different regions. Such a screen as this would, however, prolong the exposure some fifty times. In Fig. 3 are seen some striking examples illustrating the great improvement gained by the use of dyes as sensitizers in the photographing of coloured objects as compared with ordinary plates. The object photographed was a light yellow star with white centre, on a dark blue ground with black border. No. 1 is from a negative on wet collodion containing iodide and bromide of silver. No. 2 shows the result on an ordinary gelatino-bromide dry plate; No. 3 that on an orthochromatic plate, but without a screen; while No. 4 was taken on an orthochromatic with the aid of a correctly-adjusted light filter. Fig. 4 is very interesting, as showing a result obtained on Dr. Albert's orthochromatic collodion emulsion without the use of a screen. It must be remembered that collodion emulsion is itself very insensitive to light, and that we are using in conjunction with it a powerful sensitizer for yellow-green and yellow, "in the shape of an organic compound of silver," which is itself sensitive to light. Further, the picric acid which is mixed with the sensitizer no doubt aids in obtaining a better rendering by acting the part of a screen. One thing noticeable is the variation in the general sensitiveness of the emulsion with the method of using the sensitizer, *i.e.*, whether it be mixed with the emulsion, or simply poured over after the glass plate has been coated: in the former case the sensitiveness being increased four times. This is probably due to the sensitizer being brought more closely into contact with the silver salt.

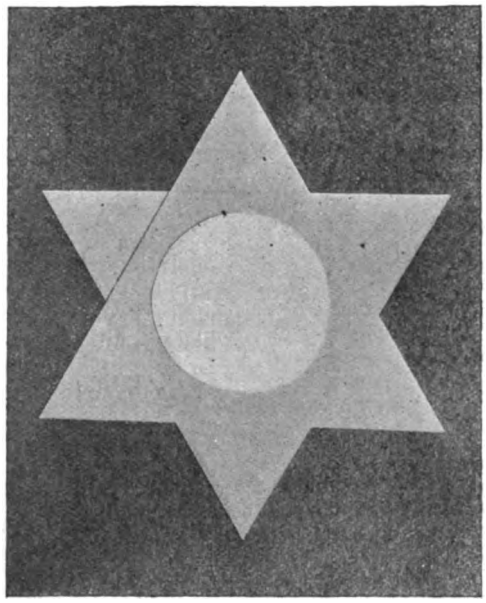

FIG. 4.—PRINT FROM A NEGATIVE ON DR. ALBERT'S ORTHOCHROMATIC COLLODION EMULSION, WITHOUT A SCREEN.

(To be continued.)

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NORTH-EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.

As a result of the deliberations of a Committee of the above Institution, formed last May, a number of important proposals have been formulated with regard to the education of Engineering Apprentices, and those destined for higher posts in engineering works. The Committee considers that the development of studious habits in apprentices should be encouraged by a system of rewards offered by employers, while the methods of selecting and training those destined to work in the higher branches of engineering and shipbuilding demand important modifications. The following are the proposals made by the Committee.

Regulations for Apprentices.

IN starting apprentices, preference will be given to those who bring the best certificates of conduct and character and the highest school-leaving certificates. The age of starting should be from 15 to 16 years.

At the end of September in each year each apprentice will be awarded marks as follows: for each approved examination passed during the year, 20 marks; for timekeeping, a maximum of 40 marks; for good conduct, perseverance, and progress in the workshops, a maximum of 40 marks.

Marks for timekeeping will be deducted at the rate of one mark for every three hours lost, but no deduction will be made for special leave, or for sickness if certified by a doctor.

Conduct marks will be awarded quarterly by the chief foremen of departments on the following scale: very good, 40 marks; good, 30 marks; fair, 20 marks; moderate, 10 marks.

An apprentice obtaining 60 marks will have the sum of 6d. added to his weekly rate of pay for the ensuing year, and for marks in excess of 60 his rate will be proportionately increased. For example, an apprentice who in any one year passed in two science subjects at an evening science school will be entitled to 40 marks, for very good timekeeping 40 marks, and for general good conduct, perseverance, and progress in the workshops a maximum of 40 marks—total for the year, 120 marks. This will entitle him to an increase of 1s. per week on his rate of pay, say, from October 1st for one year, but payments under this scheme will cease on the termination of apprenticeship or on dismissal.

Should an apprentice obtain, say, 30 marks for timekeeping and 40 marks for good conduct, perseverance, and progress, or a total of 70 marks, his rate of pay would be increased 7d. per week, and so on.

No payment under this scheme will be made to apprentices obtaining less than 60 marks, and apprentices who fail to obtain any marks for timekeeping, good conduct, perseverance, and progress will be subject to dismissal.

Apprentices commencing their apprenticeship between October 1st and March 31st will be entitled to half rates for their first year.

Promotion in the workshops will depend upon marks obtained. Should an apprentice during the first three years of his time have shown marked ability at the evening classes, and obtained maximum marks for timekeeping, perseverance, and progress in the workshops, he may, at the discretion of his employer, be allowed to spend his fourth or fifth year at college day classes, the fees for which will be paid by his employer.

At least one vacancy per annum in the drawing office will be filled by an apprentice obtaining the highest marks under the above scheme.

Regulations for Pupils.

Scheme A.—Youths who have passed through a three or four years' engineering day course at an university college, and who have obtained therefrom either an approved certificate, or a pass degree in engineering science, or in naval architecture, may be admitted into the works as pupils. They will serve a three years' pupilage, and for the first year the scale of pay will be that of an ordinary apprentice of the *third* year. The scale of pay for their last two years will be that of ordinary apprentices of the fourth and fifth years, plus 3s. and 5s. per week respectively. Those who hold a degree with honours may be admitted on the same conditions as the above, but the scale of pay for the last two years will be increased by 4s. and 7s. per week, instead of 3s. and 5s.

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Scheme B.—Youths who desire to combine workshop experience with college study, and who hold no certificate or degree from an university college, may be admitted to the works as pupils, on the production of evidence that they have received a sufficient preparatory education. A certificate showing they have passed the matriculation examination required for graduation in engineering science at a science college of university rank, or an equivalent certificate, will be accepted as evidence of this. They must give an undertaking that they will attend for at least three academical years the degree course of study at an university college during the currency of their pupilage, which will extend over a period of six years, including the time spent at college. Their pay will be that of ordinary apprentices in the corresponding years, plus 4s. per week in years subsequent to their first year's college training. (See appendix for suggested division of time.)

Scheme C.—Youths who, having entered the works as apprentices, succeed during their apprenticeship in passing the matriculation or equivalent examination prescribed under Scheme B, will for the remainder of their time be treated as pupils under Scheme B, in respect of leave to attend college day classes, promotion, and rates of pay. The time served, including that spent at college, will be a minimum of six years. It is understood that in every case the advancement of an apprentice to pupil rank is at the option of his employer, and subsequent promotion will depend solely upon merit and the requirements of the business. In selecting under Scheme C, other things being equal, preference will be given to the sons of workmen and other employés of the firm. Promotion in general, and admission to the drawing office in particular, will depend absolutely upon merit and conduct in all cases. This clause refers to Schemes A, B and C.

Premium Pupils.

In the case of pupils who pay a premium, it is recommended that, so far as college training is concerned, they shall be asked and encouraged to conform to the regulations under either Scheme A or B, whichever is more suitable to the circumstances of the individual case.

(Signed) JOHN TWEEDY,
President.
JOHN DUCKITT,
Secretary.

APPENDIX.

The time of pupils under Scheme B may be divided in any of the following ways, according to circumstances :—

First Alternative.

	Months.
Works	12
College	9
Works	15
College	9
Works	15
College	9
Works	3
Total	72

Second Alternative.

	Months.
Works	12
College	9
Works	15
College	*21
Works	15
Total	72

Third Alternative.

	Months.
College	9
Works	15
College	9
Works	15
College	9
Works	15
Total	72

Fourth Alternative.

	Months.
College	9
Works	15
College	*21
Works	27
Total	72

*Including three months' holiday in summer.

EDUCATIONAL SYSTEMS IN GREAT BRITAIN AND GERMANY.

AT the meeting of the North-East Coast Institution of Engineers and Shipbuilders, to which the foregoing recommendations of the Educational Committee were communicated, an interesting paper on "Technical Education in Germany" was read by Mr. Max Wurl. Lack of space will not permit of an account of this paper in the present issue of "Technics"; but a diagrammatic method of comparing the educational systems in vogue in England and Germany, which was exhibited and explained by Mr W. G. Spence in the course of the ensuing discussion, certainly calls for mention. Mr. Spence's diagrams are reproduced on pp. 196 and 197, and although the colours used by the author are necessarily absent, the significance of the diagrams is sufficiently clear. The principle on which the diagrams are constructed is as follows :—The vertical scales are divided into years, and the sequence of training of different classes of youths may be followed by proceeding upwards through the various rectangles of which the diagrams are composed. The horizontal breadth of each diagram represents the complete juvenile population of the country at any particular date, and the breadth of any rectangle represents the number of youths taking a particular course of study.

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Thus, in Germany, about two-thirds of the children attend the "Vorschule" (or preparatory school) from six to nine years of age, after which four courses of education are open to them. Some proceed to the gymnasium, where the education has a classical tendency. Others proceed to the "Real gymnasium," where the education has a more modern tendency. Others, again, proceed to the "Oberreal Schule," where the education is exclusively scientific and commercial. In all these cases, the age for leaving school is 18 years. Some boys, however, proceed to secondary schools at which the leaving age is 15. In all cases, a youth who passes an

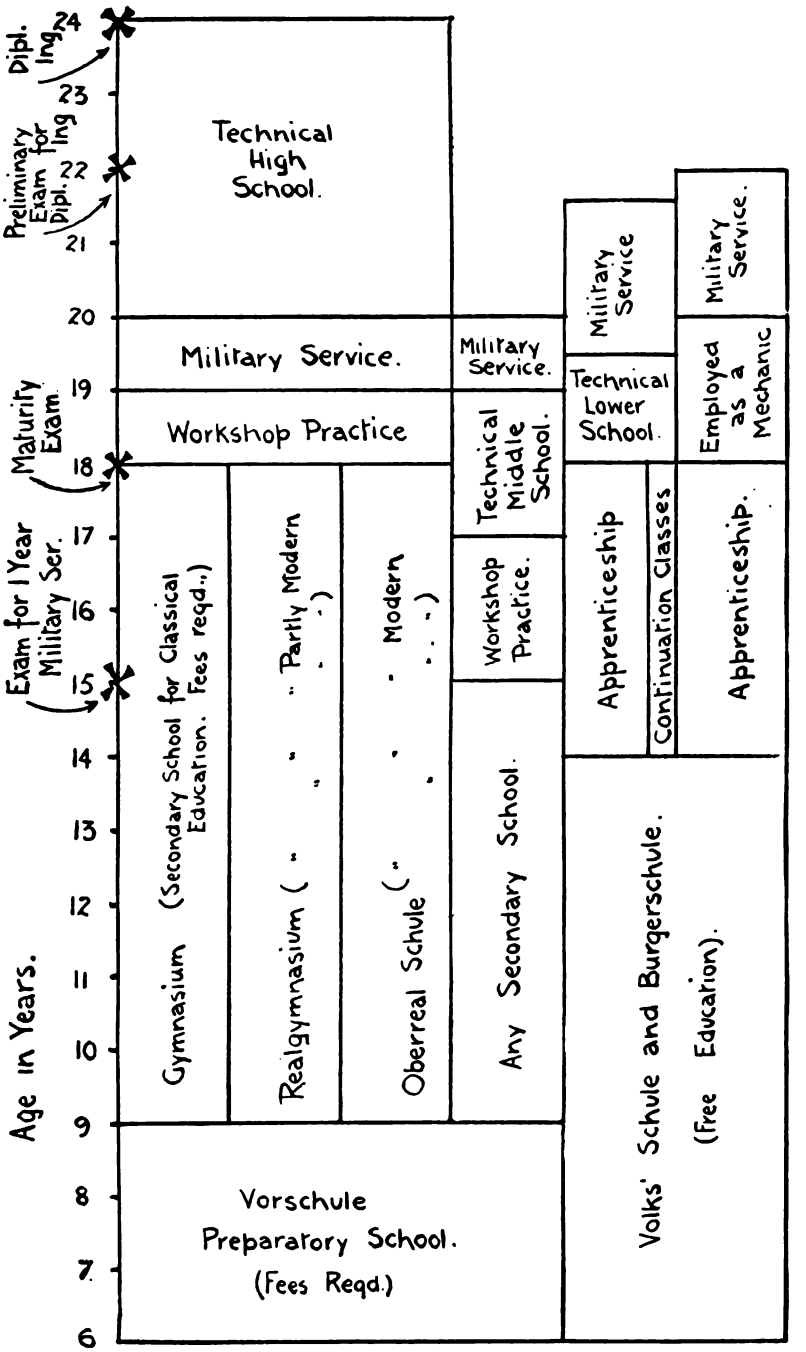

FIG. 1.—GRAPHIC REPRESENTATION OF EDUCATION IN GERMANY.

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examination at the age of 15 (first star on diagram, Fig. 1) is privileged to serve only one year in the army instead of two. When he joins the army he wears a distinctive badge, and is exempted from menial duties; after the expiration of his year of service he is eligible for appointment on the staff of reserved officers. These privileges act as a great educational incentive.

The youth who remains at school till 18, and passes an examination which entitles him to his "maturity certificate" (second star on diagram, Fig. 1), may subsequently, if he so chooses, attend the "Technical High School," and there obtain a degree. He generally spends a year (between 18 and 19) in a workshop, and spends the next year in military service. At 20 he enters the Technical High School; at 22 he must pass the Preliminary Examination (third star on diagram); and at the age of 24 he is eligible to sit for the Diploma of Engineering (Dip. Ing., fourth star on diagram).

This explanation will make the remainder of Fig. 1, as well as Fig. 2, intelligible to the reader. Fig. 2 refers to the educational possibilities of a youth in Great Britain. We may remark, however, that the evening classes in our technical institutes render it possible for a man to continue his education long after reaching the age of 21—the limiting age denoted in Fig. 2: teachers in technical institutes need hardly be told that many men avail themselves of this privilege.

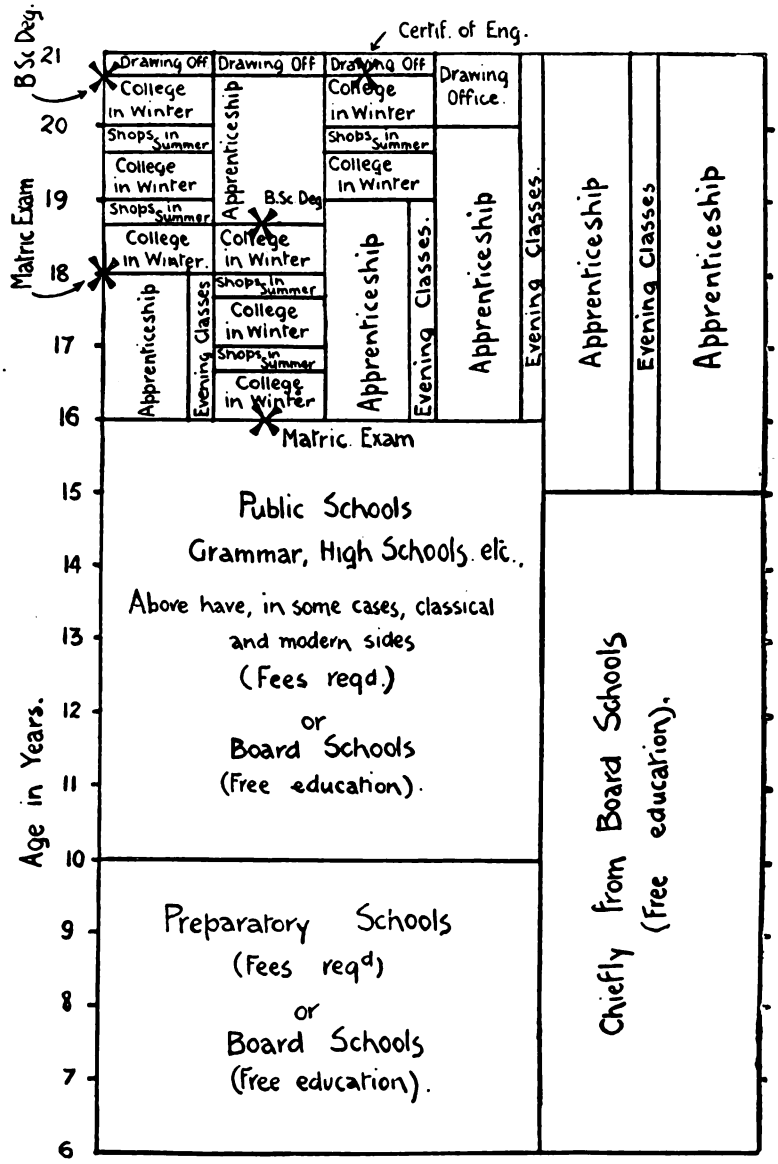

FIG. 2.—GRAPHIC REPRESENTATION OF EDUCATION IN GREAT BRITAIN.

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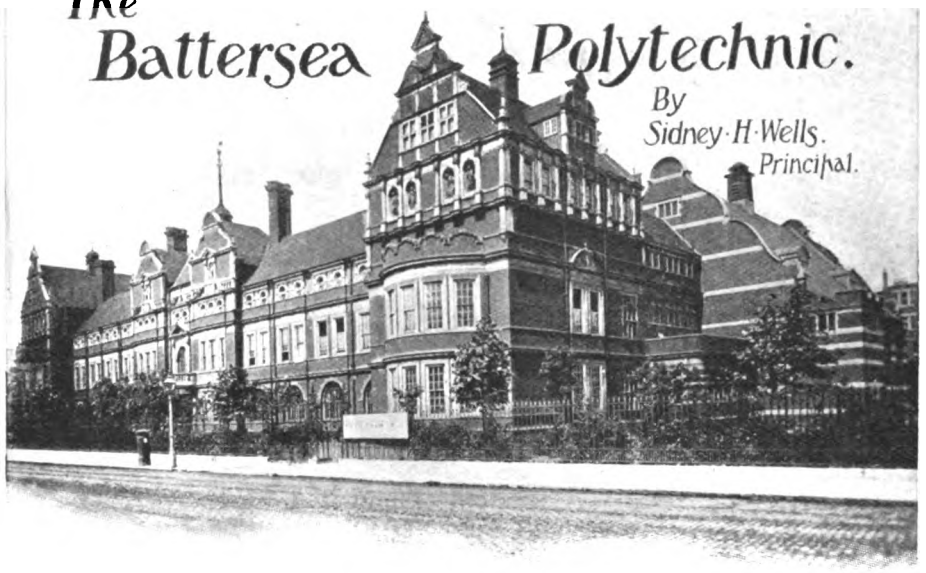
The Battersea Polytechnic.

By Sidney H. Wells. Principal.



WITHIN a few days of the appearance of this article, the Battersea Polytechnic will celebrate the tenth anniversary of its opening, on which occasion, and in connection with its annual distribution of prizes and certificates, it is to be visited by the Prince and Princess of Wales. It is probably for this reason, and because the institution may be regarded as representative of the newer type of London polytechnics, that the editors of "Technics" ask for some account of its history and work.

The Polytechnic is one of the three institutions which owe their establishment to the work of the South London Polytechnics Committee, the others being the Goldsmiths' Institute at New Cross, and the Borough Polytechnic. As the only one of the three established in buildings specially designed and erected for the purpose: and to have its foundation-stone laid, and to be publicly opened by, his Majesty the King (then Prince of Wales), the Polytechnic has from the first attracted a considerable share of public attention, and was therefore fortunate in opening with an *éclat* to which much of the continued growth and success of its work may be attributed. Although at the time of its opening it was regarded as one of the largest technical institutions in London, the buildings have since been enlarged on four occasions: the most recent addition being a block of rooms for domestic economy, which will be formally opened by the Princess of Wales on the occasion of the forthcoming Royal visit. Perhaps sufficient evidence of the increase in its work will be seen in the fact that the total of students' fees for its first term amounted to £654, whereas for the first term of the current session they reached the high figure of £2,334.

In common with other London polytechnics, the chief purpose of the institution is the provision of evening classes, which are open to students of both sexes, above the age of fifteen or sixteen. These classes, from their nature, appeal primarily to the "poorer" or "working classes," but they are by no means restricted to any social class, or limited in their character and purpose. The teacher or engineering student wishing to study for a science degree, finds equal facilities with the artisan seeking instruction applicable to his trade; and the domestic servant desirous of learning to make her own dresses, with her more leisured sister studying for qualifications in music or art. The heads of departments in mechanical engineering, electrical engineering, physics, mathematics and chemistry, with some of their chief assistants, are recognised teachers of the London University, and matriculated students attending their classes in approved courses rank in all respects as internal students of the university. Yet, side by side

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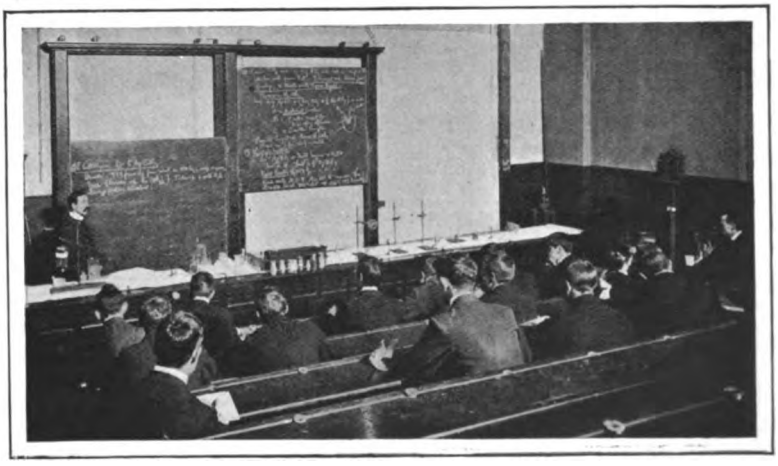
with this and other advanced work for professional examinations, there are large and successful trade classes for engineering and building subjects, men's and women's tailoring, electric wiring, upholstery, photography, and gas manufacture, and all the varied work and activities attendant upon the conduct of classes from almost the most elementary to the highest stages in some 101 different subjects, embracing almost every section of technology, science, art, music, domestic economy, languages, commercial and general subjects. The evening class fees are those common to institutions of like character, the normal fee for science and technical subjects for two evenings a week for the session being ten shillings: there are no classes with free admission. The combination of theory and practice, in the union of lecture with laboratory or workshop classes, has always been a strong feature of the evening work. During recent years, the department of mechanical engineering has specialised in classes for motor car engineers and chauffeurs: the electrical engineering department, in providing instruction in electric traction: the department of chemistry, in paper-making and testing; while the art department has developed its classes in design, and the domestic economy department in trade classes in dressmaking and tailoring.

Generally speaking, the past few sessions have seen a considerable increase in the number of students taking organised courses of study extending over two, three or more years: in the development of higher and university work; and in closer association with neighbouring industries and employers. An important example of this last condition is referred to in another part of this issue of "Technics," in connection with the early morning classes for L. & S. W. Ry. engineering apprentices. The present session has seen an extension of the same principle in the sending, by Messrs. Selincourt & Co., of some 108 of their girl apprentices for evening classes in dress-cutting and ladies' tailoring; and in an agreement with five of the neighbouring engineering works to have special regard to the attendance at evening classes of their apprentices, and to supply terminal reports as to their progress. In view of the general belief that the work of technical institutions—especially in connection with evening classes—would gain enormously in permanence and solidity by a closer association with employers of students, this recent feature of the work of the Polytechnic is of some importance. It has already given evidence of its value in the fact that the students are more punctual and regular in attendance, and keener about their class work. Their employers have agreed to allow the Polytechnic reports to influence the claims of the apprentices for higher wages and other promotion, thus proving, in a very practical way, that they regard the work done in evening classes as of real value. During the Christmas term of the current session the number of individual evening students was 2512, the women numbering about one-fourth of the whole. These are, of course, drawn from a wide area; for, although the classes in subjects common to other polytechnics and technical institutions draw their students chiefly from the immediate neighbourhood, the special classes attract students from as far east as Rochester, and south as Brighton.



From a photograph *By Edgar Senior.*

STUDENTS AT A LECTURE.

It is, however, in its day work that the Battersea Polytechnic has most developed in recent years. Recognising the possibilities in the use for day students of the rooms and equipment primarily provided

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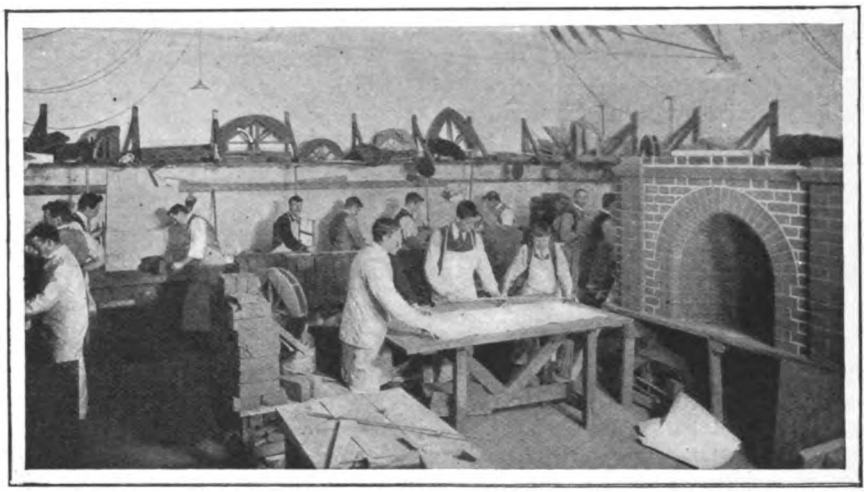
for evening classes, and the great advantages of being able to secure teachers who would devote their whole time to the interests and work of the Polytechnic, the governing body decided to establish day classes from the commencement; and the opening of the Polytechnic was attended by the formation of a technical school for boys who had passed through the public elementary schools, and now wished to derive further education with a view to a technical calling. After a year or two the school was opened to girls, and became an organised science school, being recognised as what is known as a "School in Division A." The fees are £3 per year, including the provision of books and materials: the average age of entry is thirteen, and the boys and girls work together in the same classes, except for a few subjects. For the present term the students number 182, the maximum accommodation being 200. The school has been singularly successful in maintaining a good higher division, and during the past five years its scholars have secured the considerable number of thirteen Intermediate County Scholarships, while four of its top boys have gained open Science Scholarships at Oxford or Cambridge, securing also Senior County Scholarships; other scholars having passed the higher science examinations of London University, or proceeded with scholarships to the Royal College of Science. It is often urged that the conduct of secondary day schools in Polytechnics is not their chief function, and is probably not the most useful form of day work which they might undertake; but it is certain that the Polytechnic day school has in more than one instance filled a gap in the provisions for secondary education in its district, and such schools give a rather more technical time-table than is common, and undoubtedly act as most excellent feeders for the evening classes. At the same time, it is not improbable that the next few years may see a decrease in this section of Polytechnic work, and it is quite certain that if London properly recognised her need of technical education, there would be no room in the Polytechnics for secondary day schools.



From a photo *By Edgar Senior.*

BRICK-CUTTING CLASS.

Next in order of opening, although by no means in importance, came the establishment of a Day Training School and a girls' School of Domestic Economy, the former being for the training of teachers for all domestic subjects, and the latter being one of the dozen or more schools originated by the Technical Education Board of the London County Council, for the training of girls who had obtained scholarships from the public elementary schools. The Training School has increased until it is now one of the largest in the country and possesses a high reputation. Since its opening, some 313 students have been trained in the schools, and practically no student with good diplomas has failed to secure a teaching post.

From its early days the Polytechnic has also provided day classes for senior students in science and engineering subjects; and during the last few years, these have been considerably extended and provision made

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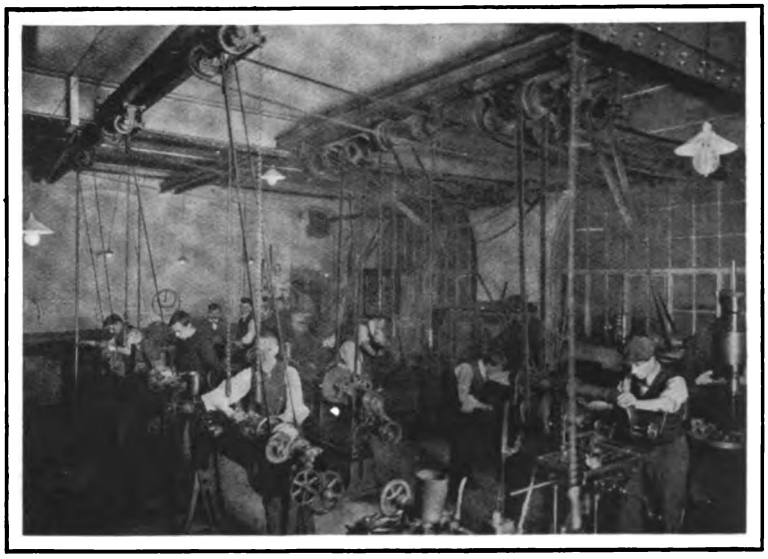
for what are sometimes known as "day college courses," extending over two or three years, open to students over fifteen years of age who possess a good general education, and requiring an attendance for 30 to 33 hours a week. There are different courses for mechanical engineers, electrical engineers, for architectural and constructional work, for technological chemistry, with complete courses for London Matriculation, for intermediate engineering and science and final science, the latter being under the recognised teachers of the University, and qualifying for internal students. The average fee is £3 per term, and the time-table of the engineering courses is similar to that found in other technical institutions and colleges. A course is now being arranged for students intending to take up motor and motor-car engineering. In the current term, the attendance of day students for these courses is 104, the majority being for mechanical or electrical engineering, and including students from as far distant as India and Mauritius. The Departments of Chemistry and Physics also provide special courses for dental and pharmaceutical students, their attendance being recognised by the various professional bodies as qualifying for their examinations.

Another important feature of the day work of the Polytechnic is that of the School of Art, which is open four days a week, and which has secured for itself a considerable reputation for design, as shown by the continued success of its students in the National Competition. The fees for full attendance vary from 32*s*. to 40*s*. per term, and the school has a good record of students who have obtained work as designers and in book and paper illustration, as a result of their training. Finally, the Polytechnic also includes, among its day work, a course of training for women teachers of calisthenics and gymnastics, with afternoon classes in domestic subjects, music, commercial subjects and languages, and in preparation for civil service examinations, with special Saturday morning classes for teachers in manual training, art, physics and chemistry. For the present term the total of individual day students number 790, of whom some 413 are taking regular courses extending over 24 to 33 hours a week. Some idea of what a beehive of industry a London Polytechnic may be, will be realised when it is mentioned that at Battersea, during the present session, classes commence in the morning as early as 8 o'clock on four days a week, and continue through the day and evening from Monday to Friday until 10·15; while even on Saturdays there are afternoon classes. Large as the building is, there is often not a single room unoccupied, and some measure of the extent of its work will be seen in the fact that during the middle weeks in November the average number of student hours per week amounted to 17,019.

In the matter of equipment the Polytechnic compares favourably with any of the similar institutions in London, and with many of the university colleges. It contains well-equipped workshops for all sections of the building trades and for engineers and smiths. There are laboratories for chemistry, elementary and advanced: for botany and physiology: for physics and electrical science: for dynamo and electric traction



From a photo *By Edgar Senior.*

THE ENGINEERING WORK-SHOP.

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work; and in mechanical engineering, for mechanics, testing of materials and hydraulics, and for steam and heat engines. The Technical Education Board of the London County Council makes annual grants for equipment, and these have enabled the Governors to obtain machines and apparatus for all kinds of experimental and practical work in the applied science and technical departments. Engineering laboratory students work with small machines for torsion and bending: with a 10-ton Wicksteed testing machine: hydraulic, reciprocating, and centrifugal pumps: with gas and petroleum engines, and with a steam-engine and boiler of 15 I.H.P.; and some modern types of petrol motors. For electrical work, the chief machines, include nine units of electrical plant of 4 to 12 H.P., so arranged that the operations with continuous, alternating, or polyphase currents may be tested under working conditions; while recent additions include examples of machinery for electric traction-work. The chemical laboratories are well equipped for organic chemistry, gas analysis, and technological analysis generally.

The teaching staff numbers 92, of whom 30 give their whole time to the Polytechnic, the remainder being evening teachers.

The income of the Polytechnic last year amounted to £17,372, in which the chief items were: Endowment, £3,500; Fees, £5,050; Grants from the Technical Education Board, £6,073; Grants from the Board of Education, £2,375.

A very usual and natural question in connection with the work of an institution of this character is as to its use and value. Few questions are more easily asked or harder to answer. The Battersea Polytechnic can not only point to the magnitude of the work it is now doing, but to a recorded list of ten years' successes of its students in winning scholarships and passing examinations which few similar institutions can equal, and to a mass of general evidence not so easy to tabulate, from students who owe their present positions in life largely to its work. During the past five years, day and evening students —excluding the Secondary School which has already been mentioned—have been successful in securing one Whitworth Scholarship (the senior for the year) and five Whitworth Exhibitions, two Royal Exhibitions, two National Scholarships, ten College or Training-School Scholarships, three Princess of Wales Scholarships in Art, with 190 exhibitions and scholarships in Science and Technology (London County Council), 9 gold, and 102 silver and bronze medals, and 99 other prizes; while twenty students have obtained the degree of B.Sc. at London University, and numbers of others have matriculated or passed the intermediate examinations, or such professional examinations as those of the Institution of Civil Engineers, British Architects, and the Colleges of Music. In May or June, 703 of its students passed various public examinations. But these are indications of its successful work rather than any true measure of it, and none know how difficult it is to state this, so much as those engaged in it. No feature of the educational work of London during the past ten years has been more remarkable than the development of the Polytechnics, and few there are who will venture to prophesy what they will be at the end of the next decade. The Battersea Polytechnic, in common with its sister institutions, has a wider aim than mere technical education; it provides gymnasia as well as class rooms, a reading room and reference library and students' common rooms, as well as laboratories and workshops; organ recitals, lectures and entertainments in its large hall, and it recognises the formation of athletic and social clubs and societies for its students as being part of its work.

THE WOOD-WORK SHOP.
From a photo by Edgar Senior.

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REVIEWS.

Strength and Elasticity of Structural Members. By R. J. Woods, M.E., M. Inst. C.E., Fellow and Assistant Professor of Engineering, Royal Indian Engineering College, Cooper's Hill. pp. xii. + 310. (London : Edward Arnold, 1903.) Price 10*s.* 6*d.* net.

From a broad point of view, the object of the engineer is to utilise the properties of matter in the service of man. So wide a field of work needs many sub-divisions, one of the most important of which is the erecting of structures. This branch of applied science calls for wide and definite knowledge, and success in it can scarcely be attained by one unacquainted with mathematical methods of reasoning. Many students are inclined to shirk mathematical investigations, and for this tendency they are not wholly to blame ; some books on elasticity, for instance, deal with the subject from a point of view so abstruse and remote from the exigencies of engineering practice, that it is hard to convince a student that he can benefit himself by working through them. Mr. Wood's work is free from such defects, and should prove of the greatest importance and interest to engineering students. The subject is necessarily treated from a mathematical point of view, but all investigations have been simplified as much as possible, and there is scarcely a page on which some point of vital importance to the engineering student is not investigated and elucidated. Numerous tables are interspersed throughout the book, and problems of practical importance, with their answers, are given at the end of each chapter. Graphic methods are frequently and effectively used. The book is well written and illustrated, and the only complaint which can be made about it is that an index has not been added.

Practical Lithography. By Alfred Seymour. pp. xii. + 104. (London : Scott Greenwood & Co.) Price 5*s.* net.

Amongst the many methods in use at the present day for illustrating books and papers, lithographic processes hold an important place. To the intelligent general reader an account of these processes is interesting, as showing how many collateral inventions and improvements have been pressed into service. To the professional lithographer such an account is of even greater interest, and of supreme value, since it may suggest methods of overcoming difficulties which have not yet been surmounted, and may lead to improvements of the greatest importance. The lithography of to-day is by no means a simple process, and the succinct *résumé* of the art given by Mr. Seymour is sure to prove useful. Every detail of present-day methods is described, from the selection and graining of stones to the use of the electric motor to work the printing-press. Lithography appears to be a term all too narrow to cover the processes at present employed by the lithographer ; specially prepared metal plates are now used in place of stones. This innovation is being forced upon us by the need for rotary printing where speed is required : lithographic stones can only be employed with the slow and tedious flat-bed press. The last three chapters are devoted to photo-lithography. The book is well written and illustrated, and is provided with a useful index.

Photographic Lenses. A Simple Treatise. By Conrad Beck and Herbert Andrews. pp. 288. (London : R. & J. Beck.) Price 1*s.* net.

In this little book an attempt is made to give the amateur in photography a simple and intelligible account of the properties of lenses, especially those used in photography. The amateur may find it necessary to know how to select a lens, and how to use it to the greatest advantage when he has obtained it ; such a knowledge may certainly be obtained from the work under consideration. More difficult problems are dealt with, such as the equivalent (or principal) planes of a lens system ; but these parts of the subject require more detailed treatment to be of much practical value. A lens-testing bench made for the Photo-mechanical Department of the Manchester School of Technology is described, and its method of use is briefly dealt with. An error made on p. 12 may be noted ; it is not strictly accurate to say that a pin-hole image will be equally well-defined for all positions of the screen. Lord Rayleigh has pointed out that, on the Wave Theory of Light, there is a certain position of the screen which gives the best definition.

The Locomotive Simply Explained : A First Introduction to the Study of the Locomotive Engine. By Chas. S. Lake. pp. 72. (London : Percival Marshall & Co.) Price 6*d.* net.

This little book will form an interesting and instructive guide to the beginner desirous of knowing something about the modern locomotive steam-engine. Though no very exhaustive method of treatment is adopted, the reader is familiarized with the salient features which present themselves to the locomotive engineer. The text is illustrated with twenty-six diagrams and half-tone engravings.

Educational Woodwork. By A. C. Horth, Member of the Art and Manual Training Department, Roan School for Boys, Greenwich. pp. 158. (London : Percival Marshall & Co.) Price 3*s.* 6*d.* net.

The author of this volume has aimed at providing "a graduated educational course of woodwork, based on a succession of joints, with a model following each joint, and, as far as possible, based on it." The writing is clear and concise, and some excellent illustrations have been provided. This book should prove very useful to teachers of manual training in woodwork.

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ANSWERS TO QUERIES.

STUDENTS wishing for the solutions of problems, or assistance in their scientific or technical studies, are invited to consult the Technical Editor by letter. Queries should be accompanied by the name and address of the sender, together with a *nom de plume* for publication. Queries obtained from text-books or examination papers should be accompanied by particulars of the sources from which they are derived. Queries should reach us before the 10th of the month to be answered in the next month's issue.

CHEMIST.—Explain fully why the formula for the molecule of hydrogen is written H_2, and of Oxygen O_2.

In answering such questions it is safest to assume as little as possible, but the wording of the question shews clearly enough that the atomic theory may be taken as a starting-point, and it is probable that the question was set for the purpose of ascertaining whether the student has a clear idea of the basis of Avogadro's hypothesis and of the conclusions which one may derive therefrom.

The first point to be discussed, therefore, is the basis of Avogadro's hypothesis, which depends, in the first place, on the observation that when two gases unite to form a third one the relative volumes of the three gases may always be expressed by simple whole numbers (providing, of course, that they are measured at the same temperature and pressure, as we shall here assume throughout). This, and similar observations, are comprised by *Gay-Lussac's Law of Volumes*.

Now this law shows that the number of molecules in equal volumes of different gases, under the same conditions as to temperature and pressure, must also be expressible in simple whole numbers, and the most probable, or, at least, the most simple explanation of this is, that the numbers are identical, which is the *hypothesis of Avogadro*. The mathematical development of the atomic hypothesis, applied to the physical properties of gases, confirms the foregoing view.

We may assume, then, that equal numbers of molecules of different gases occupy equal volumes, hence we may assign any gas molecule the volume 1.

Now we are in a position to proceed to the particular cases of hydrogen and oxygen, where we know that 1 *vol. oxygen* + 2 *vols. hydrogen give* 2 *vols steam*, i.e., 1 *mol. oxygen gives* 2 *mols. steam*.

So that, as each molecule of steam must contain at least one atom of oxygen, and for every molecule of oxygen two of steam are produced, the molecule of oxygen must be divisible into two equal parts, and, therefore, contains 2, 4, 6, etc., atoms. Now it has never been found that the molecule of oxygen can be divided into *more* than two parts, so that we must assume that there are only two atoms of oxygen to the molecule, whence the formula O_2.

To determine whether the hydrogen molecule is composite, therefore, we must ascertain whether there are any cases in which hydrogen yields more than its own volume of another gas. We have such a case in the formation of hydrogen chloride from hydrogen and chlorine, in which the following volume-relationships are observed :—

1 *vol. hydrogen* + 1 *vol. chlorine give* 2 *vols. hydrogen chloride*, i.e., 1 *mol. hydrogen gives* 2 *mols. hydrogen chloride*.

So that each molecule of hydrogen is divided into two equal parts; as it has never been found to divide into more than two parts, we must write the formula of the molecule as H_2.

OCULIST.—The "far-point" for a certain person is two metres from the eye. What kind of spectacle-lens would enable this person to see distant objects? Give the focal length and the dioptric power of the lens required.

For the person to see distant objects clearly the rays from them (which are practically parallel) must be caused to diverge from a point at two metres distance from the eye, by means of a lens. Since parallel rays are to be rendered divergent by passing through the lens, the lens must be divergent. Further, parallel rays, falling on a divergent lens, give rise to emergent rays which diverge from the second principal focus of the lens: thus the latter point must be at a distance of two metres in front of the lens, or the focal length of the lens must be equal to + 2 metres.

The *power* of a lens, in dioptres, is equal to the reciprocal of the focal length expressed in metres, with the sign changed. Thus the power of the lens required is equal to − 0·5 dioptres.

TYPO.—What is the reason that ordinary printer's type, when set up, can be converted into a fairly compact mass by pouring a little water over it? Water is not a sticky substance, and I cannot understand how it produces the above effects.

The surface of a liquid possesses properties which differ from those possessed by the body of the liquid. A drop of liquid can hang for an indefinite time from the under surface of a glass plate, owing to the fact that the surface of the drop acts somewhat as if it were an elastic bag. This contractile tendency of a liquid surface is known as *surface tension*, and it is this property which causes the wet type to adhere together. If an ordinary camel's-hair brush is dipped into water, the hairs remain apart so long as they are submerged; but on removing the brush from the water, the hairs cling together, just as if they were enclosed in a contractile bag.

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BAT.—One glass is half full of wine, another half full of water. A teaspoonful of wine is taken from the first glass to the second, and a teaspoonful of the mixture from the second to the first. Is the wine transferred from the first glass greater or less than the water transferred from the second glass ?

Let N = the number of teaspoons to the half glass ; then the first operation leaves N − 1 teaspoons of wine in the first glass, while the second operation transfers $\frac{1}{N+1}$ of a teaspoon of wine, and $\frac{N}{N+1}$ of a teaspoon of water to it. Hence the wine in the first now amounts to $\left\{N - 1 + \frac{1}{N+1}\right\}$ teaspoons, and the loss is $\frac{N}{N+1}$ teaspoons. Hence the loss of the first glass in wine, is equal to that of the second in water.

KAY.—Obtain the value of the following indefinite integral :—

$$\int \frac{dx}{\sin x + \sin 2x}.$$

$\sin x + \sin 2x = \sin x + 2 \sin x . \cos x$

$$= \sin x (1 + 2\cos x) = 2 \sin \frac{x}{2} \cos \frac{x}{2}$$

$$\times \left\{\left(\cos^2 \frac{x}{2} + \sin^2 \frac{x}{2}\right) + 2\left(\cos^2 \frac{x}{2} - \sin^2 \frac{x}{2}\right)\right\}$$

$$= 2 \sin \frac{x}{2} \cos \frac{x}{2} \left\{3 \cos^2 \frac{x}{2} - \sin^2 \frac{x}{2}\right\}$$

$$= 2 \sin \frac{x}{2} \cos^3 \frac{x}{2} \left\{3 - \tan^2 \frac{x}{2}\right\}$$

$$= 2 \frac{\sin \frac{x}{2}}{\cos \frac{x}{2}} \cdot \frac{\cos^2 \frac{x}{2}}{\cos^2 \frac{x}{2} + \sin^2 \frac{x}{2}} \cdot \cos^2 \frac{x}{2} \left\{3 - \tan^2 \frac{x}{2}\right\}$$

$$= 2 \tan \frac{x}{2} \cdot \frac{1}{1 + \tan^2 \frac{x}{2}} \cdot \cos^2 \frac{x}{2} \left\{3 - \tan^2 \frac{x}{2}\right\}$$

$$\therefore \int \frac{dx}{\sin x + \sin 2x}$$

$$= \int \frac{\left(1 + \tan^2 \frac{x}{2}\right) \cdot \left(\frac{1}{\cos^2 \frac{x}{2}}\right) dx}{2 \tan \frac{x}{2} \left(3 - \tan^2 \frac{x}{2}\right)} \quad . \quad (1)$$

Let $z = \tan \frac{x}{2}$;

then $dz = \frac{1}{2} \cdot \frac{1}{\cos^2 \frac{x}{2}} \cdot dx$

Substituting in (1), we obtain

$$\int \frac{(1 + z^2)\, dz}{z (3 - z^2)} = - \int \frac{(-1 - z^2)\, dz}{z (3 - z^2)}$$

$$= - \int \frac{(3 - z^2 - 4)\, dz}{z (3 - z^2)} = - \int \frac{dz}{z} + 4 \int \frac{dz}{z (3 - z^2)}.$$

Now $\frac{1}{z (3 - z^2)}$

$$= \frac{1}{3} \cdot \frac{1}{z} + \frac{1}{6} \cdot \frac{1}{\sqrt{3} - z} - \frac{1}{6} \cdot \frac{1}{\sqrt{3} + z}.$$

Thus, when $z = \tan \frac{x}{2} > \sqrt{3}$, the value of the integral is equal to

$$\frac{1}{3} \left\{\log \tan \frac{x}{2} - 2 \log \left(\tan^2 \frac{x}{2} - 3\right)\right\}$$

$$= \frac{1}{3} \log \frac{\tan \frac{x}{2}}{\left(\tan^2 \frac{x}{2} - 3\right)^2}.$$

When $z = \tan \frac{x}{2} < \sqrt{3}$, the value of the integral is equal to

$$\frac{1}{3} \left\{\log \tan \frac{x}{2} - 2 \log \left(3 - \tan^2 \frac{x}{2}\right)\right\}$$

$$\frac{1}{3} \log \frac{\tan \frac{x}{2}}{\left(3 - \tan^2 \frac{x}{2}\right)^2}.$$

DOBBS.—A man hangs from a rope which passes over a frictionless pulley : to the other end of the rope hangs a weight equal to the mass of the man. If the man commences to climb the rope what happens to the weight ; and how does the man's motion differ from that which would result if the remote end of the rope were fixed ?

As the man pulls himself upwards, he pulls the rope downwards. Thus the force which produces the upward motion of the man is equal in magnitude to the force transmitted by the rope to the weight. Since the man and the weight are equal in mass, and equal forces act on the two, both will ascend at the same rate. Half of the work expended by the man will be utilized in raising himself, and half in raising the weight ; thus the man will raise himself at only half the rate that would result from the same expenditure of power if the remote end of the rope had been fixed.

PEDRO.—A 50-volt arc lamp is to be used on 100-volt alternate current mains, while the cost of running the lamp is to be determined from the reading of a coulomb-meter. Will the cost be the same whether the pressure be reduced from 100 to 50 volts by using a non-inductive resistance, or a choking coil, or a step-down transformer ; and if not, which arrangement will render the cost, as determined from the coulomb-meter, the least.— *City and Guilds Electric Lighting and Power Transmission, Ordinary Grade*, 1897.

The current required by the arc lamp will be the same in all three cases ; and since the voltage across the terminals of the lamp is also invariable, the watts consumed by the lamp will be the same in all three cases. When a non-inductive resistance or a choking coil is used to reduce the pressure, the current required by the lamp will be identical with the current drawn from the mains, and passing through the coulomb-meter. Therefore, in these two cases

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the cost of supply, as determined from the reading of the coulomb-meter, will be the same.

If a step-down transformer is used to reduce the pressure, the pressure in the secondary circuit must be half that in the primary; consequently the current in the secondary circuit will be nearly double that in the primary; it would be exactly double but for the unavoidable losses in the transformer. The current in the secondary circuit is that which works the lamp; if the coulomb-meter is placed in the primary circuit, and is therefore traversed by the current drawn from the mains, the reading will be about half as great as in the two cases discussed above.

Thus, under the conditions specified, the cost, when a step-down transformer is used, will be about half as great as when a choking coil or non-inductive resistance is used.

A specimen of dilute sulphuric acid is found to have a density of 1·2902 at 15° C. What volume of this acid must be taken to make a litre of normal sulphuric acid on dilution with water?

By reference to "density tables" it is seen that—

38 per cent. acid has a density = 1·2890 at 15° C.
40 per cent. „ „ = 1·3060 „

So that the strength of the specimen lies somewhere between 38 and 40 per cent., and its exact strength may be deduced in the following way:—

From the table figures an increase of 2 per cent. in strength raises the density from 1·2890 to 1·3060 = 0·0170 (*A*)

But the density of the specimen is greater than that of 38 per cent. acid by 1·2902 − 1·2890 = 0·0012 . . (*B*)

So that it contains $\frac{0{\cdot}0012}{0{\cdot}0170}$ of 2 per cent. more than 38 per cent. = 0·141 per cent., *i.e.*, it contains 38·141 per cent. of pure H_2SO_4.

Now as sulphuric acid is dibasic, 1 litre of a normal solution contains ½ its molecular weight, 98, in grams = 49 grams.

We must, therefore, take such a volume of acid as will contain 49 grams of pure acid.

The specimen contains 38·141 grams of pure acid in every 100 grams, or 1 of pure acid in $\frac{100}{38{\cdot}141}$ grams, so that 49 grams of pure acid are contained in $\frac{100 \times 49}{38{\cdot}141}$ grams; but we wish to measure this out by volume, and not by weight, and to obtain the volume of this weight of acid we have merely to divide by its density, *i.e.*, 1·2902. Hence the required volume is $\frac{100 \times 49}{38{\cdot}141 \times 1{\cdot}2902}$, or 99·6 cc. to the nearest drop.

OCTAVE.—How can the wave-length of a very high note, such as that emitted by a Galton's whistle or a bird call, be determined?

The whistle or bird call is placed at a distance of about two feet from a smooth vertical surface, such as an even wall. Stationary waves are formed by the combined actions of the waves travelling toward the wall and those reflected from it. If a sensitive flame is moved backwards and forwards in a direction perpendicular to the wall, it will flare at each antinode, and burn quietly at the nodes. The wave-length of the note emitted is equal to twice the distance between two successive nodes, or two successive antinodes.

A sensitive flame can be obtained by burning coal gas at a pressure of 9 to 10 inches of water by means of a pinhole burner. The gas should be obtained from a weighted gas-bag; a stop-cock should be placed in the connecting tube, and adjusted so that, in the absence of disturbance from sound waves, the flame just does not flare. Where the ordinary supply of gas is used it is best to place a piece of fine wire gauze over the pinhole burner, and light the flame above the gauze.

CORRECTION OF ERROR.—*On p. 98 of the January issue, third line in right-hand column, a numerical error occurs. This line should read—*

$$100 \times 2240 \times 620 = 134{,}400{,}000 \text{ ft.-lbs.}$$

The final result obtained should be 90·9 kilowatt-hours, instead of 95·5 kilowatt-hours. The Editors beg to thank Mr. J. W. Cable for drawing their attention to this error, and thus giving them an opportunity to rectify it.

OPEN QUERIES.

QUERIES such as the following, which can best be answered by those who have had special experience, will be left open to the readers of TECHNICS to answer. Prizes will be awarded to the best answer to each of the following queries; for particulars see p. 207. No answer should exceed 1,500 words; the greatest brevity, consistent with thoroughness, is desirable.

ALPHA.—Is it possible to disinfect the air, say, of a sick room by means of electricity? If so, what is the reaction and which would be the cheapest and most effectual way of doing it? I may mention that I have a small induction coil, also a small ozoniser.

LOCO.—Shew that the gain in power obtained by throttling the exhaust of a locomotive, and so increasing the draught, is greater than the loss due to throttling. What percentage of the full-way exhaust opening should the throttled exhaust be?

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"TECHNICS" COMPETITIONS.

A GOLD MEDAL and £200

To be awarded Annually to the "Technics" Prizeman.

£50 IN PRIZES OFFERED IN THIS ISSUE.

PARTICULARS of 15 competitions were given in the January number of "Technics." The present issue contains particulars of 12 competitions, for which money prizes amounting, in the aggregate, to £50 will be awarded.

At the end of the year, a prize of £200 in cash, and a Gold Medal, will be awarded to the competitor who has shown the most care, thought, and accuracy in the year's competitions.

£50 IN PRIZES.

General Rules.

Competitors are requested to note the following rules:—

All writing must be on foolscap paper. Only one side to be written upon, and a reasonable margin left.

Competitors should see that their drawings are sent either rolled or flat—flat preferred. They must not be creased. They must also be executed in black ink.

N.B.—All drawings, and each page of MS., must bear a *nom-de-plume*, and must be accompanied by a closed envelope containing the name and address of the Competitor. The outside of the envelope must bear the Competitor's *nom-de-plume* only.

The Editors reserve the right to publish, without further payment, contributions that gain prizes. Should any article or drawing that has not gained a prize be published in the magazine, payment will be made at the usual rate.

Should the best answer in any competition be deemed of insufficient merit, the Editors reserve the right to withhold the prize.

All competitions should be addressed to the Competition Department, "Technics," 3 to 7, Southampton Street, Strand, W.C., and must reach these offices not later than March 10th. Results will be published as soon as possible.

In each case the work will be submitted to an expert competent to declare which is the best practical suggestion, design, or article.

HOMEWORK PRIZES.

In May next, valuable prizes will be awarded to the students forwarding the best homework books to the Editors of "Technics." Full particulars will be published later.

GENERAL COMPETITIONS.

1. The best syllabus of practical work, to elucidate the quantitative laws of magnetism and electricity; together with a detailed description of the necessary apparatus. Prize £10.

2. The best critical article dealing with the respective advantages and disadvantages of steam engines, petrol engines, and secondary cells and motors, for use with motor cars and carriages. Prize £4.

3. The best article on possible advances in the chemical industries. Prize £3.

4. The best article on "How to arrange ordinary water pipes so as to minimize the risk of their breakage during frosty weather, and how to temporarily mend them when broken." Prize £3.

5. The best short article on "Scientific principles and calculations applied to bread-making." Prize £2.

6. The best design for the floor of the vestibule of an art museum, to be carried out in mosaic work. Prize £2.

7. For the best set of answers to each of the four sets of questions coming under the head of "Special Competitions," p. 208. Prize £5 for each set of answers.

8. For the best answer to each of the two open queries on page 206. Prize £3 for each answer.

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SPECIAL COMPETITIONS.

Questions Bearing on Articles in this Number.

I.

Questions on "The Continuous-Current Dynamo."

1. The curve given in Fig. 14, p. 177, for obtaining the core loss, is confessedly of a rough practical character. Consult Dr. Thompson's "Design of Dynamos," and Hawkins and Wallis, "The Dynamo," as to other methods of estimating the core loss. Write a brief essay on the subject, giving curves and practical examples of their application.

2. Make estimates of the ampere-turns required for the teeth in the case of the 400 k.w. dynamo, first by means of some published method other than that given in the present article, and then by some method of your own devising. Discuss the subject.

3. What methods are in vogue for determining the magneto-motive force required for the air gap? Quite irrespective of the time required by such calculations, what do you consider would be a good method of precisely estimating this quantity?

4. Given an observed no-load saturation curve, how would you proceed to analyse it in order to obtain an approximate idea of the distribution of the magneto-motive force amongst the component parts of the magnetic circuit?

II.

Questions on Prof. Barrett's Paper.

1. In Fig. 3 are given **B-H** curves for pure iron and for aluminium and silicon alloys. In physical testing **B** and **H** are the correct terms in which to plot such results. To expedite dynamo calculations, the magneto-motive force in ampere-turns per centimetre is more suitable for the abscissae. Re-plot Prof. Barrett's curves on this basis, and compare with the curve Fig. 17, p. 180 of the article on "The Continuous Current Dynamo."

Were large castings of such alloys to become commercially available in unlimited quantity at 6d. per kilogram, what effect would it have upon the design of continuous-current dynamos? Study the alternative arrangements of core and yoke in Figs. 21A, 21B, 21C, and 21D of the article on the Continuous Current Dynamo, and take these into consideration in your discussion of the subject. A little thought will show that quite different considerations affect the choice of materials for magnet cores and for yokes respectively. Discuss this point.

2. In how far might the commercial application of Prof. Barrett's investigations decrease the core loss in continuous-current dynamos? Consider not only the hysteresis but also the foucault current losses. Which alloys would you choose for the pole-shoes, in designs where these are separate from the magnet cores?

3. In what departments of engineering will the results of Prof. Barrett's investigations be likely to be applied with advantage?

4. Compare Prof. Barrett's results for the specific resistances of various alloys with the results obtained by other investigators. A good many researches have, during the last fifteen years, been conducted on the general subject of the specific resistances and temperature coefficients of various alloys. Consult the reports on these researches.

III.

Questions on Photography.

1. It is generally considered that the darkened substance produced when silver chloride is exposed to light is of the nature of a subchloride. What are the main objections to this theory, and what evidence has been brought forward to show that metallic silver is formed?

2. In orthochromatic photography, dyes are employed to increase the sensitiveness of silver salts; what conditions should they fulfil?

3. What would guide you, in the general appearance of a dye in solution, as to what colours it would be likely to sensitize for?

4. The photographic action of light on silver iodide is enormously increased by the presence of silver nitrate; on silver bromide the action of silver nitrate is less marked. Why is this? What considerations would you be guided by in selecting substances to act in this manner?

IV.

Structural Design.

1. Find the value of the bending moment at intervals of a foot for the load given in Fig. 15, p. 159, and plot these values as ordinates on a line representing the span of the beam.

The bending moment due to the weight of the beam itself need not be included.

2. State clearly, concisely, and in your own words, the two necessary conditions for equilibrium in a solid body, such as a beam.

3. Plot the values of the bending moments due to a load of uniformly varying intensity on a beam 120 inches long.

The load is to vary from zero at the left reaction, to an intensity of five tons per foot run at the right reaction.

4. A plate-girder bridge, thirty feet long by three feet deep, is exposed to a uniform horizontal wind pressure of 40 lbs. per square foot. What would be the maximum bending moment, due to the wind alone (a) when the wind is normal to the web plate, (b) when the direction of the wind is inclined at an angle of forty-five degrees to the main girders?

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PERSONAL ITEMS.

MR. HERBERT TOMLINSON, B.A., F.R.S., is retiring from the position of Principal at the South-West London Polytechnic, Chelsea, which he has held since the opening of the institute.

IN a lecture on *Shadows*, delivered at the Royal Institution of Great Britain on January 15, Lord Rayleigh said that some hitch seems to have occurred in connection with Marconi's transatlantic wireless telegraphy, though no doubt messages have been sent successfully.

Mr. EDWARD DIXON has been appointed Superintendent of the British Electrical Exhibit at the St. Louis World's Fair. Mr. Dixon is an "old student" of the Central Technical College, South Kensington.

AT the meeting of the Chemical Society on December 16, Mr. A. C. V. Hann and Dr. A. Lapworth communicated Part IV. of a paper on optically active esters of β-ketonic and β-aldehydic acids, and a paper on condensation of aldehydes with menthyl acetoacetate.

MR. S. A. F. WHITE, who has held the post of Demonstrator in Natural Philosophy at King's College, London, since 1895, has been appointed Professor of Mathematics in succession to Professor Hudson.

THE discovery that active nerves and contracting muscles emit a form of radiation closely resembling Blondlot's N-rays, was announced by M. Augustin Charpentier at the meeting of the Academy of Sciences on Jan. 4. M. Charpentier is well known as an original worker in connection with physiological optics and nerve impulses.

THE death of Sir William Allan, which occurred on December 28, has deprived the House of Commons of one of its most prominent engineering members. Sir William Allan formed one of the deputation which waited on the present First Lord of the Admiralty to urge reform in connection with the status of naval engineers. He was a strenuous opponent to the water-tube boiler.

ON January 15th a deputation from the Liverpool University waited upon the Finance Committee of the Liverpool Corporation and called attention to the claims of the new University to Municipal support. It is reported that the Finance Committee will recommend a vote of £10,000 a year to be made in aid of the University.

ON January 14th, at a meeting of the Chemical Society of the Technical College, Finsbury, Mr. S. J. Johnstone, Research Chemist at the Imperial Institute, read an interesting paper on "The Production, Manufacture, and Analysis of Rubber." The lecture was amply illustrated by lantern slides.

ON Friday, February 26th, Lord Kelvin will present the certificates and prizes at the annual Conversazione of the Northampton Institute, Clerkenwell.

ON Friday, January 21st, Mr. H. Bohle read an interesting paper at the Leeds local section of the Institution of Electrical Engineers, on the conditions necessary for the paralleling of alternators. From an exhaustive study of the writings on this subject, Mr. Bohle concludes that the permissible speed variation of the engine is really greater than is generally stipulated for in modern practice.

AT an extraordinary meeting of the Yorkshire College Council, held on January 20th, at the Philosophical Hall, Leeds, the following resolution was proposed and carried unanimously:—"That the Bill to merge the Yorkshire College in the Victoria University of Yorkshire and to transfer all the property and liabilities of the Yorkshire College to the Victoria University of Yorkshire, and for other purposes, which has been deposited in the Private Bill Office of the House of Commons, be approved, subject to such additions, alterations, and variations as Parliament may think fit to make therein."

IT is announced by the New York correspondent of the *Yorkshire Post* that Dr. W. J. Morton, of New York, has succeeded in effecting cancer cures with the aid of radium. His treatment consists in administering internally a solution of sulphate of quinine, and then holding near the cancer a minute quantity of radium. Fluorescence is produced in the quinine, and this kills the cancerous growth. It is stated that three proven cases of cancer have been cured in this manner.

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EDITORIAL.

At the present time, the number of technical students throughout the country amounts to half a million, and is increasing daily. In addition to those attending courses at technical and scientific institutions, there are many others to whom technical information is of the greatest possible value, but who are so situated that they can obtain this only through the medium of the Press. It is, therefore, a matter of surprise that no magazine devoted to the interests of this large body of men has heretofore been started. There are numerous excellent magazines which treat of special branches of technology, but these appeal to experts rather than to students. Further, the increasing dependence of industrial processes on scientific discoveries and principles is working a revolution in the methods of science teaching; it is daily becoming clearer that the most interesting and instructive scientific problems are to be found in the industrial applications to which science has given birth. Thus it is a matter of vital importance that students of science should possess a comprehensive grasp of technological processes, and that technical students should have a wide and accurate knowledge of science.

The aim of this magazine is to meet the wants arising out of these conditions. The articles appearing in TECHNICS will be specially written for students by the highest authorities. Our readers will consequently gain the latest and best information on all questions connected with science and technology. Important advances in educational methods and appliances will be described, and improvements made by the staff of any institution will be brought to the notice of teachers and students generally.

Everything which is calculated to advance the cause of scientific and technical progress will be dealt with. Teachers will find it an invaluable aid in their professional careers, and students will gain from it a breadth and comprehensiveness of knowledge which could not otherwise be obtained.

To the scientific or technical specialist, TECHNICS should prove of the greatest value, since it affords a ready means of obtaining information in all branches of Science and Technology. At the present day there is no other publication which aims at covering so wide a field of knowledge as this magazine.

Large money prizes will be offered for the solutions of problems, and the answers to questions of scientific and technical interest. Teachers may feel assured that students who spend time and trouble in these competitions are materially improving their knowledge.

Teachers are invited to co-operate in carrying out the aims of this magazine by furnishing articles for publication, as well as suggestions and advice. Students are invited to inform us of the difficulties which they encounter in their studies, in order that we may afford them expert assistance.

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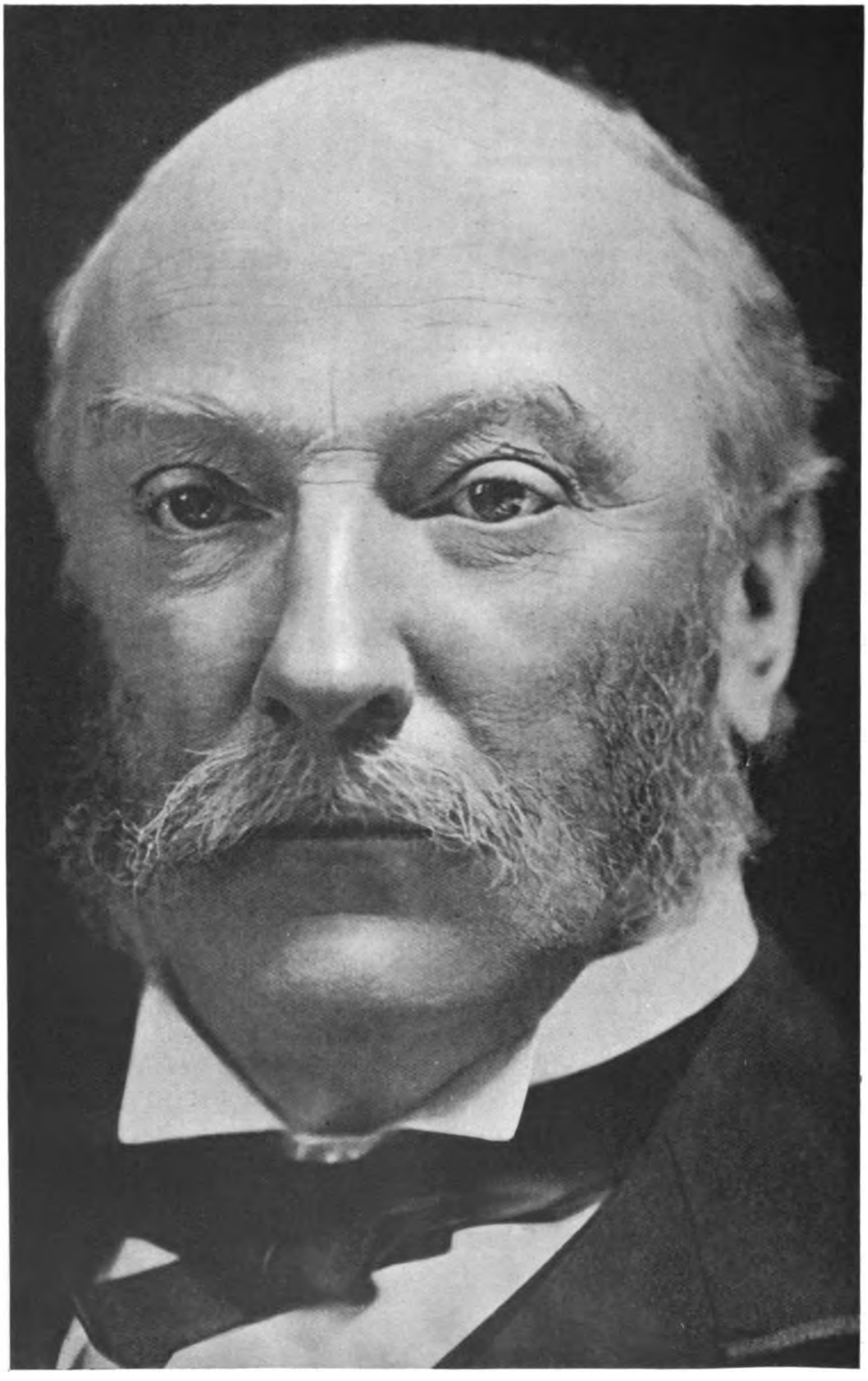

The Right Hon. LORD RAYLEIGH, O.M., M.A., D.C.L., LL.D., Sc.D., F.R.S.

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TECHNICS

A MAGAZINE FOR TECHNICAL STUDENTS.

VOL. I. MARCH, 1904. NO. 3.

PROGRESS OF SCIENCE AND TECHNOLOGY.

SO far, the popular interest in radium shows no signs of flagging. Many lecturers, anxious to exhibit some properties of this interesting substance to their audiences, have been put to great expense, and have wasted much valuable time in attempting to overcome difficulties which, in fact, are insurmountable. For instance, the phenomenon discovered by Sir William Crookes, and embodied by that eminent investigator in the beautiful little instrument termed the "spinthariscope," cannot be exhibited to large audiences. The scintillations of the zinc sulphide screen are produced by the α rays of radium, and these rays are incapable of penetrating more than a very few millimetres of air. Moreover, the scintillations, when produced, must be observed with a fairly powerful lens, in order that they may be individually seen. The light emitted is very feeble, so that there is no chance of projecting a magnified image on a screen. In a recent lecture, Sir Oliver Lodge showed the *appearance* of the spinthariscope screen by placing two metal sheets, perforated with numerous fine holes, in the projection lantern. The sheets should be placed face to face in the position ordinarily occupied by the lantern slide, and moved slowly one over the other: bright spots of light appear and die away on the screen, thus mimicking the phenomenon seen in the spinthariscope. For making spinthariscope screens, the hexagonal variety of zinc sulphide should be used. The substance which appears to fluoresce most brilliantly under the action of radium is *willemite*, a native anhydrous silicate of zinc. Professor Soddy has shown that, when a crystal of this substance is surrounded by the emanation of radium, a beautiful green light is emitted. This experiment can be exhibited to a large number of people, if a reasonable amount of radium can be procured. Since glass, or even paper, cannot be traversed by the emanation, the radium must be placed inside a vessel which also contains the willemite crystal.

Radium

One of the most remarkable discoveries in connection with radium is that helium is spontaneously produced, presumably by the disintegration of the radium atoms. This discovery, due to Sir William Ramsay, has recently been confirmed in a very striking manner by M. Curie and Professor Dewar. About four-tenths of a gram of radium bromide was left for three months in a small glass vessel connected to a vacuum tube and a mercury manometer. A continual evolution of gas occurred, but a spectroscopic examination of the light emitted by the vacuum tube showed that only hydrogen and mercury vapour were present. The same specimen of radium bromide was then taken by Professor Dewar to the Royal Institution, where it was sealed up in a tube of fused quartz, the gases evolved being drawn off, and examined spectroscopically. No gas appeared to be present except nitrogen. After thoroughly removing the gas, the radium was sealed up and returned to Paris. About three weeks afterwards, M. Deslandres examined the tube by connecting tinfoil electrodes, fastened to its outside surface, to the terminals of an induction coil. He found that the spectrum of the light emitted comprised all of the well-known lines of helium.

Production of Helium from Radium

It has been pointed out by Mr. C. T. R. Wilson that the presence of a very small amount of radium in the sun would account

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for the continual emission of solar heat and light: incidentally it would explain the presence of helium in the sun's atmosphere. There are also many other phenomena which may be due to the same cause. It has long been known that sunlight will discharge electrified bodies on which it falls; radium radiations act in a similar manner. It is necessary to remark, however, that ultra-violet light produces similar effects, and if the γ rays of radium are identical with X rays, which in their turn are only extremely short ultra-violet rays, this similarity is easily accounted for. It is possible that "sun-burns" may be produced by solar radiations, which differ but little from the radiation emitted by radium. The β rays of radium are of a fairly penetrative character, and, from time to time, cases have been reported, by Alpine climbers, of photographic plates which have become blackened on development, although they had never been exposed; in such cases the action may have been due to β or γ rays which penetrated the wooden walls of the dark slide.

The Radio-activity of the Sun

It is a well-known fact that the upper regions of the atmosphere are at a higher potential than the lower regions; much independent evidence has also been advanced to prove that the earth itself is negatively charged. These results follow naturally if we assume that the sun emits radiations somewhat similar to those given off by radium. Mr. George Simpson, writing in *Nature* for January 21st, points out that the α rays, which consist of positively charged bodies of atomic dimensions, would become absorbed in the upper regions of the atmosphere, since air is practically opaque to them. The β rays, which consist of negatively charged particles, are much more penetrative, and might reach the earth. Experiments have proved that in the night-time the potential difference between the upper and lower regions of the atmosphere diminishes to a considerable extent; while in the day-time the potential difference rises till mid-day is reached. At first sight it would appear that the α and β rays, received from the sun during the day, would continually increase the potential difference between the higher and lower regions of the atmosphere; but it must be remembered that the accumulation of positively charged particles in the upper atmosphere will tend to stop the negatively charged particles, so that it is not unnatural that a maximum effect should occur about mid-day.

Atmospheric Electricity

If it be admitted that the earth is negatively charged, then a first approximation to a theory of terrestrial magnetism is easily arrived at. Looking down on the earth from above the North geographical pole, the direction of rotation of the earth will be left-handed, or opposite to that in which the hands of a clock revolve. If the negative charged electrons on the earth are carried round in the daily rotation, they will produce a magnetic field similar to that due to positive electrons rotating in a right-handed direction; *i.e.*, to an electric current flowing round the earth in a right-handed direction. Such a current would produce a S. magnetic pole at the north geographical pole of the earth, and a N. magnetic pole at the south geographical pole: results which are in complete agreement with experiment. When, however, we attempt to proceed a step further, and account for the secular, annual, and daily variations in the earth's magnetism, serious difficulties arise. On the other hand, the magnetic storms which generally occur at maximum sun-spot periods become fairly intelligible. At such periods the sun is in a state of maximum activity, and is therefore discharging electrons at a maximum rate. Perhaps at no very distant date the whole of these phenomena will be co-ordinated by one comprehensive theory.

Terrestrial Magnetism

The discovery of radium bids fair to be eclipsed by the still more sensational discovery of N rays. The letter N stands for Nancy, the home of M. Blondlot, the discoverer of these rays. A note on this form of radiation was included in the February number of this magazine; but so fast do things move, that already our knowledge has been greatly extended. M. Charpentier states, that if a zinc sulphide screen is exposed to sunlight, and then taken into a dark room, the proximity of a contracted muscle, or an active nerve centre, causes the phosphorescent light emitted to perceptibly increase. This phenomenon is not due to heat, since the radiations emitted by a cold-blooded animal, such as a frog, produce similar results. The spinal column can be traced from end to end by the aid of a faintly phosphorescent zinc sulphide screen. When a muscle contracts, the nerve which is active in producing this contraction can be traced throughout its length to its termination in the brain or the spinal marrow. The activity of the brain may be measured by observing the brightness of a screen placed near the head. Thus a person can "see

N Rays

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himself think." A certain part of the brain is particularly active during speech, and this part can be localised by similar means.

E. Meyer announces that N rays are emitted by plants. It appears that their emission is due to the activity of the protoplasm, since it at once ceases if the plant is chloroformed.

Wave lengths of N Rays

It is strange that, outside Nancy, scarcely anyone has been able to verify the existence of N rays. Professor Rubens has repeated Blondlot's experiments, entirely without success. Professor Lummer suggests that Blondlot's observations may be explained by a consideration of the peculiarities of the eye when viewing small, feebly luminous objects. M. Charpentier, however, is a specialist on physiological optics, and it is improbable that he should have been deluded in this way. Further, such an explanation could not account for the following remarkable results. The first determination of the wave length of N rays was made by Sagnac, who found this magnitude to be equal to about one-fifth of a millimeter. M. Blondlot now announces that the wave length is very small. He states that N rays comprise a complete octave, the wave length varying from about 8 to 17 millionths of a millimeter. In comparing N rays with light rays, it must be remembered that the orange light emitted by a flame containing sodium, has a wave length equal to nearly 600 millionths of a millimeter. As a source of N rays, Blondlot used the glower of a Nernst lamp, intercepting all visible and ultra-violet rays by means of two plates of aluminium, two sheets of black paper, and a wooden board 2 inches thick. The radiations which penetrated this formidable series of obstacles were refracted by aluminium prisms, and a spectrum was obtained which could be observed by the aid of a feebly phosphorescing screen of zinc sulphide. The wave-lengths were determined by the aid of a diffraction grating of 2,000 lines to the centimeter, and also by the method of "Newton's rings." Aluminium was found to have a refractive index of 1·04 for the shorter rays, and 1·85 for the longer rays. Aluminium lenses were made, and it was found that these could be used to focus N rays just as an ordinary lens focusses light. The possibilities opened up by these discoveries are of the most interesting character. It may be found possible to produce a focussed image of the brain on a zinc sulphide screen, and to study the various centres of activity in much the same way that we now study the shape of the bones in the living subject by the aid of X rays. The most puzzling feature of these discoveries is that water is opaque to N rays, a piece of damp cardboard entirely intercepting them; while yet they can traverse the flesh, which contains a considerable amount of moisture.

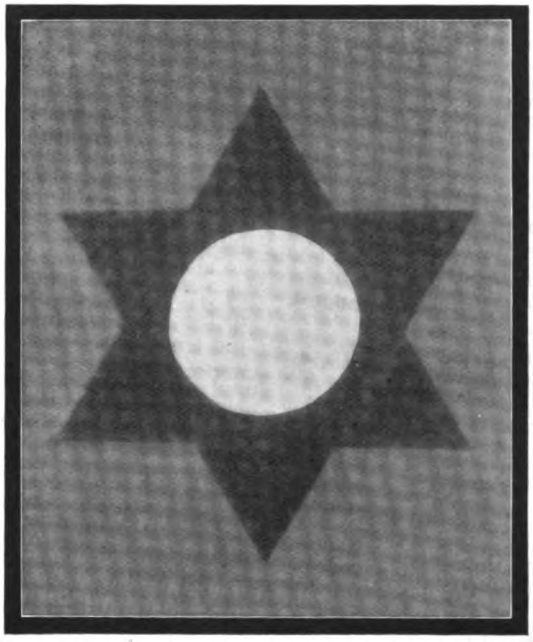

FIG. 1.—ULTRA-VIOLET PHOTOGRAPH OF YELLOW STAR WITH WHITE CENTRE ON BLUE GROUND.
(By Edgar Senior.)

Elsewhere in this issue Mr. Senior describes a screen, invented by Professor R. W. Wood, which is transparent to ultra-violet rays, but is quite opaque to visible light. If one of these screens is interposed between the eye and the positive crater of an arc lamp, absolutely nothing can be seen, yet a photograph of an object can be readily obtained by focussing the invisible ultra-violet rays which traverse the screen, on a photographic plate. Fig. 1 is an ultra-violet photograph of a yellow star, with a white centre, on a blue ground; it was obtained by Mr. Senior, using a screen made in the manner described by Professor Wood. Orthochromatic photographs of the same star were reproduced in the February number of this magazine.

Photography by Ultra-Violet Light

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In honour of Dr. Ostwald

Following the precedent set on the occasion of the twenty-fifth year of the doctorate of van't Hoff, the *Zeitschrift für Physikalische Chemie* has recently issued a *Jubelband* in commemoration of the 25th year of Professor Ostwald's doctorate. The volume, which consists of more than nine hundred pages, contains a portrait of Professor Ostwald, a sketch of his career by Professor van't Hoff, and a bibliography of his writings compiled by Dr. Walden, of Riga. This introduction is followed by a series of thirty-four original papers written by his former students, and it is of interest to note that in addition to sixteen German papers there are six contributions from Russia and America, three from England, and one each from France, Greece, and Scandinavia. As might be expected, most of the papers deal with various aspects of the theory of electrolytic dissociation and its application to conducting solutions of all kinds; but there are four papers on catalysis, and single papers referring to most of the problems of modern physical chemistry. The whole volume is a striking illustration of the work accomplished by one of the modern pioneers of chemical science.

Occlusion and Inclusion of Solvents by Crystals

One of the most interesting papers in the Ostwald *Jubelband* of the *Zeitschrift für Physikalische Chemie* is by Professor T. W. Richards on "The Inclusion and Occlusion of Solvents by Crystals." It was found that the percentage of water in air-dry barium chloride was reduced from 14·780 to 14·760, when the average diameter of the particles was reduced from 0·45 to 0·05 mm. The latter percentage is, however, in excess of that calculated from the formula $BaCl_2$, 2 H_2O, which requires only 14·744% H_2O, and it is suggested that a certain proportion of water is included in cavities so minute that they cannot be broken by any ordinary process of powdering or grinding. To get rid of the water the salt may be heated, in order to explode the enclosing cells, but this is not efficient unless the temperature is high enough to soften the crystals, and it is advisable, when possible, to fuse the substance, or to sublime or distil it in a dry atmosphere, in order to eliminate the last traces of moisture. Neglect of these precautions has an important influence on the accuracy of atomic weight and other determinations, and in the case of hydrated salts there is no method known by which included water can be eliminated without decomposing the salt.

Supra-renal Extract

The active principle of supra-renal extract, which was first isolated by Abel and Crawford, and named by them "epinephrin," has been investigated by a number of workers. Dr. Jowett, who describes his results in the *Proceedings of the Chemical Society*, has succeeded, by an ingenious process of methylation and oxidation, in establishing its probable constitution, and assigns to it the formula

$$CH_3 NH \cdot CH_2 \cdot CH (OH) \cdot C_6H_3 (OH)_2.$$

Although the substance is obviously related to the active compounds of the neurine group, and resembles especially the bilineurine or choline first investigated by Strecher, its formula gives little indication of its extraordinary physiological properties. So relatively simple a compound should not be difficult to synthesise, and allied synthetical compounds may prove to be of considerable value in therapeutics. Dr. Jowett's work on pilocarpine will be familiar to many of our readers, and it is a matter for congratulation that work of this kind is being so successfully prosecuted by English chemists.

Expenditure on Education in the United States

There is room for much diversity of opinion as to the excellence of the educational methods at present in vogue in the United States; but as to the importance which an American citizen attaches to technical education, there can be no shadow of a doubt. In Dr. Walmsley's final report on *Transatlantic Engineering Schools and Engineering*, read before the Institution of Electrical Engineers on February 11th, some interesting amplications of his preliminary report were given. The following table gives the capital expended and invested in university colleges, and schools of technology, in the United States:—

CAPITAL EXPENDED AND INVESTED.

Subject.	Universities and Colleges.	Schools of Technology	Totals.
	£	£	£
Grounds and Buildings . .	30,100,000	3,420,000	33,520,000
Apparatus and Machinery. .	3,600,000	804,000	4,404,000
Productive Funds	32,370,000	2,880,000	35,250,000
Libraries	2,430,000	150,000	2,580,000
Total . . .	68,500,000	7,254,000	75,754,000

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It thus becomes evident that a total sum of nearly *seventy-six millions sterling* has been expended or invested in educational institutions in the United States; and further inquiry shows, that the greater part of this expenditure has occurred during the last ten years. A very large proportion of this sum has been derived from private benefactions. These latter have not exclusively been given by millionaires, but by hard-headed business men of all kinds and in various stations of life: all, however, anxious to secure the commercial prosperity of their country.

Producer Gas and Power

At a meeting of the Junior Institution of Engineers, held on February 5th, Mr. Hal Williams read an interesting paper on *Producer Gas Power for Factories, Cold Stores, and Freezing Works*. After criticising the Dowson system of small pressure producer gas plants, the author dealt with the recovery of bye-products from bituminous gas plants. It was pointed out, that while the only two bye-products available are sulphate of ammonia and steam, it does not pay to recover the former from plants of less than 3,000-h.p. Steam, however, can be generated as a bye-product from any gas engine over 50-h.p., the method being to employ a boiler patented by Mr. Wilson, placed on the exhaust pipe of the gas engine, which acts really as an exhaust silencer. With this boiler, as much as 2 lbs. of water can be evaporated, and steam raised to 100 lbs. pressure, per brake horse-power hour. Steam raised in this way might be very valuable to certain industries requiring a small proportion of it for their manufacturing processes. Taking the average run of factory steam engines throughout the country, not less than 4 to 5 lbs. of coal per B.H.P. hour are required. In the bituminous gas plant, so much as 150,000 cubic feet of power gas, having a calorific value of 130 to 150 B.T.U's, can be generated from 1 ton of slack coal. A gas engine of 40-b.h.p. requires from 70 to 80 cubic feet of power gas per B.H.P. hour; larger engines only require from 60 to 70 cubic feet per B.H.P. hour. This means that, whereas a steam engine requires from 4 to 5 lbs. of coal per B.H.P. hour, a gas engine will only require 1 lb. Further, the coal used in the former case must be of a better quality than that used in the latter. The numerous advantages of the suction gas plant were pointed out. With this type of plant one B.H.P. hour can be generated from 1 lb. of anthracite coal, with the great advantage that gas is only generated by the engine as it is required, and that consequently there is no waste.

Acoustic Experiments

Now-a-days, when so many expensive educational buildings are being erected, it is surprising that so little attention is paid to the design of lecture rooms with especial view to their acoustic properties. The architect not infrequently acts as if he were reluctant to trammel his artistic inventiveness with any utilitarian considerations; with the consequence that many lecture rooms are unsuitable in the highest degree for the purposes for which they were constructed, and in some cases much money has to be spent on rendering them even passably useful. In a recent lecture on *Shadows*, of which an account is given elsewhere in this issue, Lord Rayleigh emphasised the fact that when sound is emitted by a source in a room, reflections at the walls, floor, and ceiling produce multiple images; so that, in listening to a speaker, we hear not only the sounds which he directly produces, but also the sounds proceeding from a host of acoustic images formed by reflection at the walls, etc. It is thus somewhat surprising that we hear the voice of a speaker in a room so well as we commonly do. In some cases, however, the reflections of the speaker's voice produce great trouble and annoyance to listeners. A lecture room should be designed so that acoustic reflections produce the least possible annoyance to the audience: this much is well recognised. If, however, we wish to design a room so that its acoustic properties shall be as good as possible, we find very little trustworthy data to go upon. In some rooms a speaker's voice echoes most dismally when he alone is present; but when the room is moderately full of people, no traces of an echo can be detected. Perhaps, in such cases, we have to deal with the tendency of sound to creep along a surface; in some instances, horizontal shelves fastened round the walls have been found to improve the acoustic properties of a room. An expedient sometimes resorted to is to hang sheets of paper from wires stretched across a room; little, if any improvement can, however, be obtained in this way.

The Osmium Lamp

Some particulars of the osmium lamp were given by Mr. James Swinburne, in his article on Incandescent Electric Lamps, which appeared in the February number of this magazine. These lamps are now made by the Gasglühlicht und Elektricitäts-gesellschaft of Vienna. Each lamp comprises three loops of osmium wire, the total length of the wire being 40 cms., and its diameter 0·1 mm. At present they

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are made only for pressures up to 55 volts; at that pressure the smallest size of lamp has a candle-power of 32 British standard candles. The properties of these lamps have recently been studied by Professor F. G. Baily, M.A., who has published some interesting figures in *The Electrician* for February 12th. Fig. 2 is drawn from these figures. The current traversing the lamp is plotted horizontally; values for the P.D. across the terminals of the lamp, when the current has any specified value, can be found by inspection of the curve marked "P.D. in volts," the numbers being read on the right-hand side of the diagram. It at once becomes apparent that the resistance of the filament, unlike that of the ordinary carbon glow-lamp, increases with the temperature. The efficiency, corresponding to any specified current, may be found by inspection of the second curve, the values of the candle-power per watt being read on the left-hand side of the diagram. The high efficiency of the lamp is very noticeable: more than 0·6 candle-power per watt can be obtained, comparing favourably with the well-known figure of 0·25 candle-power per watt for an ordinary electric glow lamp. This great efficiency appears to depend on the high temperature to which the osmium filament may be raised without danger. Mr. Baily increased the current traversing the filament of a carbon glow lamp, till the latter emitted light of the same colour as that due to the osmium lamp, in which case both filaments were probably at the same temperature; he then found that both lamps were equally efficient. Dr. Wedding, of the Berlin Technical High School, has found that the life of the osmium lamp averages about 2,000 hours, though some lamps run for upwards of 4,000 hours. The low voltage of the osmium lamp appears to constitute its chief disadvantage; but in cases where groups of lamps are required to be lighted at the same time, a number of these lamps might be connected in series.

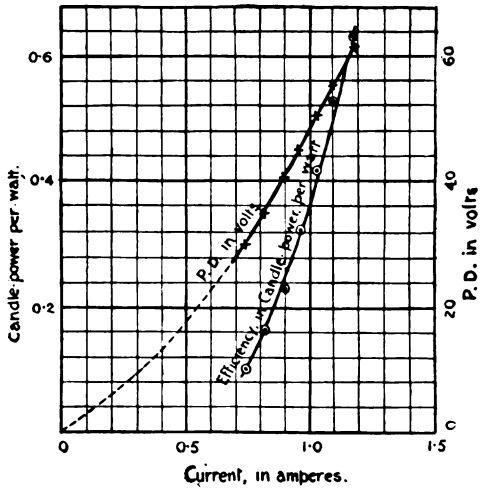

FIG. 2.

Mr. Kershaw's article on the "Electrolytic Production of Aluminium" in this number of "Technics," points to the revolution which may be worked in an industry by the successful application of scientific principles. At the present day the whole of the world's supply of aluminium is manufactured electrolytically; no other method can even compete in the production of this metal. The present cheapness of aluminium has profoundly influenced many other industries, and has given us, in some cases, the means of achieving the most remarkable results at a minimum cost. The uses of thermit in welding iron are now well recognised, although they will probably be greatly extended in the future. In the course of his article, Mr. Kershaw refers to a point which, though apparently insignificant, is really at the bottom of the success at present achieved. In the solid state commercial aluminium has a specific gravity of about 2·66, while the mixture of cryolite and refined bauxite has a specific gravity of about 2·98. Thus, if fusion produced proportional alterations in the specific gravities of these substances, the melted aluminium would float on the surface of the bath, and it would be a matter of difficulty to prevent the occurrence of oxidation. In fact, however, the fused mixture of cryolite and bauxite has a specific gravity of about 2·14, while the fused aluminium has a specific gravity of about 2·54. Consequently the molten aluminium collects at the bottom of the bath, whence it can be readily withdrawn and cast into ingots. Another point of importance should be noticed. In the Hall process the bath is heated from without, with the result that the molten contents come into contact with the walls of the containing vessel, and produce the speedy destruction of the latter. In the Héroult process the walls of the vessel are protected by a crust of the congealed electrolyte; this result is rendered possible by the circumstance that, in the Héroult bath, the heat is supplied internally by the dissipation of the energy of the electric current.

Electrolytic Production of Aluminium

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SHADOWS.

REPORT of a Lecture delivered at the Royal Institution of Great Britain, on January 15, 1904,
BY THE RIGHT HON. LORD RAYLEIGH, O.M., M.A., D.C.L., LL.D., Sc.D., F.R.S.

(Revised by the Author.)

MY subject is shadows, in the literal sense of the word—shadows thrown by light, and shadows thrown by sound. The ordinary shadow thrown by light is familiar to all. When a fairly large obstacle is placed between a small source of light and a white screen, a well-defined shadow of the obstacle is thrown on the screen. This is a simple consequence of the approximately rectilinear path of light. Optical shadows may be thrown over great distances, if the light is of sufficient intensity: in a lunar eclipse the shadow of the earth is thrown on the moon: in a solar eclipse the shadow of the moon is thrown on the earth. Acoustic shadows, or shadows thrown by sound, are not so familiar to most people; they are less perfect than optical shadows, although their imperfections are usually over-estimated in ordinary observations. The ear is able to adjust its sensitiveness over a very wide range, so that, unless an acoustic shadow is very complete, it often escapes detection by the unaided ear, the sound being sufficiently well heard in all positions. In certain circumstances, however, acoustic shadows may be very pronounced, and capable of easy observation.

The difference between acoustic and optical shadows was considered of so much importance by Newton, that it prevented him from accepting the wave theory of light. How, he argued, can light and sound be essentially similar in their physical characteristics, when light casts definite shadows, while sound shadows are imperfect or non-existent? This difficulty disappears when due weight is given to the consideration that the lengths of light waves and sound waves are of different orders of magnitude. Visible light consists of waves of which the average length is about one forty-thousandth of an inch. Audible sound consists of waves ranging in length from about an inch to nearly forty feet: the wave length corresponding to the middle C of the musical scale is roughly equal to four feet. It is, therefore, no matter for wonder that the effects produced by sound waves and by light waves differ in important particulars.

Moreover, the wave length is not the only magnitude on which the perfection of the shadow depends; the size of the obstacle, and the distance across which the shadow is thrown, must also be taken into consideration. The optical shadow of a small object, thrown across a considerable distance, partakes of the imperfections generally observed in connection with sound shadows.

It was calculated by the French mathematician, Poisson, that, according to the wave theory of light, there should be a bright spot in the middle of the shadow of a small circular disc—a result that was thought to disprove the wave theory by a *reductio ad absurdum*. Although unknown to Poisson, this very phenomenon had actually been observed some years earlier, and was easily verified when a suitably arranged experiment was made.

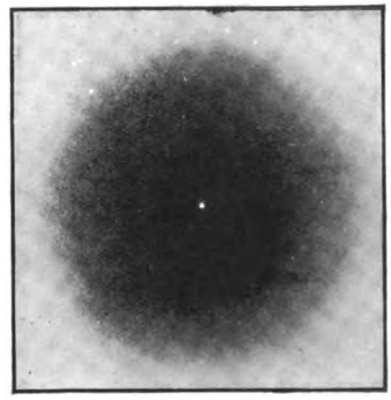

FIG. 1.—REPRODUCTION OF A PHOTOGRAPH OF THE SHADOW OF A SILVER PENNY PIECE.

Under suitable conditions a bright spot can be observed at the centre of the shadow of a threepenny-bit. The coin may be supported by three or four very fine wires, and its shadow thrown by sunlight admitted at a pin-hole aperture placed in the shutter of a darkened room. The coin may be at a distance of about fifteen feet from the aperture, and the screen at about fifteen feet beyond the coin.

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To obtain a more convenient illumination, a larger aperture in the shutter may be filled by a short focus lens, which forms a diminutive image of the sun; this image serves as a point source of light. A smaller disc has some advantages. Fig. 1 is reproduced from a photograph of the shadow of a silver *penny* piece, struck at the time of the Coronation. The shadow, formed in the manner just described, was allowed to fall directly on a photographic plate; after development a negative was obtained, in which the dark parts of the shadow were represented by transparent gelatine, while the bright parts were represented by opaque deposits of silver. To obtain a correct representation, a contact print was formed from the negative in the usual way, upon a lantern plate; and from this Fig. 1 has been reproduced.

It is at once evident that at the centre of the shadow, where one would expect the darkness to be most complete, there is a distinct bright spot. This result has always been considered a valuable confirmation of the wave theory of light.

I now propose to speak of acoustic shadows—shadows thrown by sound. The most suitable source of sound for the following experiments is the bird call* (Figs. 2 and 3), which emits a note of high pitch—so high, indeed, that it is inaudible to most elderly people. The sound emitted has two characteristics, valuable for our purpose—the wave length is very short; and the sound is thrown forward, without too much tendency to spread, thus differing from sounds produced by most other means.

FIG. 2.—PLAN OF BIRD CALL.

Since the sound emitted is nearly inaudible, some objective method of observing it is required. For this purpose we may utilize the discovery of Barrett and Tyndall, that a gas flame issuing under somewhat high pressure from a pinhole burner *flares* when sound waves impinge on it, but recovers and burns steadily when the sound ceases. The sensitiveness of the flame depends on the pressure of the gas, which should be adjusted so that flaring just does not occur in the absence of sound. If the bird call is directed toward the sensitive flame, the latter flares so long as the call is sounded, and no obstacle intervenes. On interposing the hand about midway between the two, the flame recovers and burns steadily. Thus the sound emitted by the bird call casts a shadow, and to this extent resembles light.

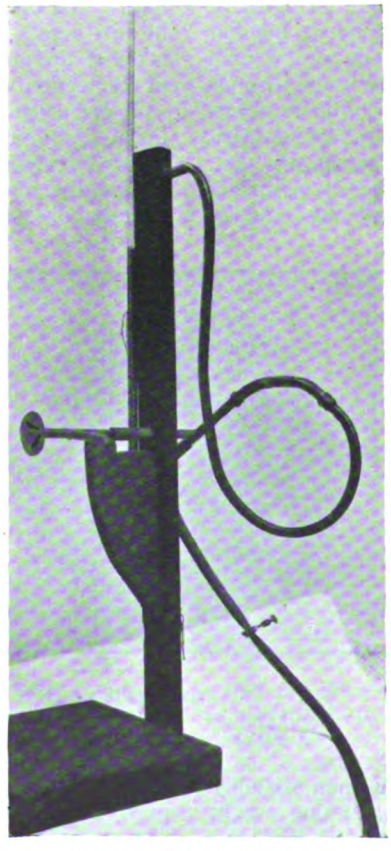

FIG. 3.—THE BIRD CALL.

It will now be shown that the sensitive flame flares when it is placed at the centre of the acoustic shadow thrown from a circular disc, but recovers in any other position within the shadow; thus proving that there is sound at the centre of the shadow, although at a small distance from this point there is silence. The part of the flame which is sensitive to sound is that just above the pinhole orifice, so that it is necessary to arrange the bird call, the centre of the disc, and the pinhole orifice in a straight line. (Fig. 4.) For the disc, it is convenient to use a circular plate of glass about 18 inches in diameter with a piece of black paper pasted over its middle portion, a

* The sound emitted by a bird call is due to a stream of air from a circular aperture in a thin plate, which impinges centrally upon a similar hole in a parallel plate held at a little distance. Bird calls are easily made. The first plate, 1 or 2 cms. in diameter, is soldered to the end of a short supply tube. The second plate may conveniently be made triangular, the turned-down corners being soldered to the first plate (Fig. 2). In constructing calls of medium pitch, ordinary tin-plate may be used. The holes may be 1 mm. or ½ mm. in diameter, and the distance between them as small as 1 mm. In any case the edges of the holes should be sharp and clean. There is no difficulty in obtaining sound waves as short as 1 cm.

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small hole being cut in the *paper* exactly at the centre of the disc. The glass disc is hung by two wires, and the positions of the bird call and sensitive flame can be adjusted by sighting through the hole in the paper. If the disc is caused to oscillate in its own plane, the flame flares every time that the disc passes through its position of equilibrium, and recovers whenever the disc is not in that position. The analogy between this experiment, and that in which a bright spot is formed at the centre of the optical shadow of a small disc, is sufficiently obvious.

Before leaving these interesting phenomena, I should like to give some indication of their theoretical explanation. Let spherical waves be supposed to spread out from the source; then at a considerable distance from the source the radius of curvature of a wave will be so large that a limited portion of a wave may be treated as if it were plane. We may thus assume that plane waves travel up to the imaginary plane in which the circular disc is situated. At a given instant, all points in the plane of the disc are subjected to the same kind of wave disturbance. This disturbance is oscillatory in character, consisting of a to-and-fro motion which is completed in a certain small interval of time, termed the *period* of the waves. The disturbance at each point may be considered to give rise to a secondary wave, or wavelet, which spreads out with a uniform velocity; and the disturbance at any point beyond the plane may be considered as due to the combined action of all the wavelets arriving there from the various points of origin.

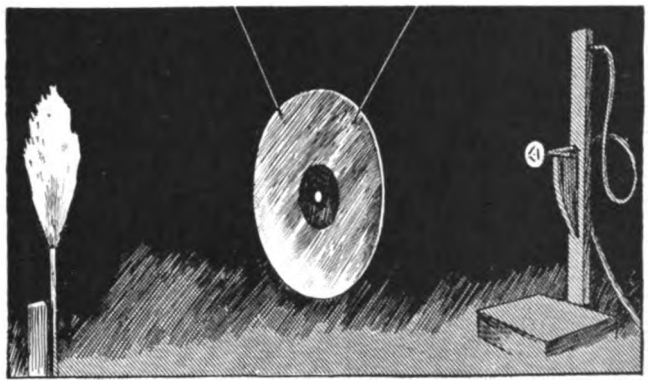

FIG. 4.—APPARATUS FOR DEMONSTRATING THE PRESENCE OF SOUND AT THE CENTRE OF THE ACOUSTIC SHADOW OF A DISC.

Let us now consider the nature of the resultant disturbance at a point on the axis of the disc. At any instant wavelets arrive there from all points in the plane of the disc, except from points of the disc itself. If we divide the plane of the disc into narrow rings or zones concentric with the disc, then wavelets which started simultaneously from different points of a given zone will arrive simultaneously at the point on the axis of the disc, since all have travelled through equal distances. But the zones farthest from the edge of the disc are farthest from the point on the axis; thus we may choose the breadths of the zones in such a manner, that the time required for a disturbance to travel from the middle of one zone to the given point on the axis, is shorter than the time required for the disturbance from the next exterior zone to reach the same destination, by an interval equal to half the period of the waves.

Let the disturbance derived from the zone nearest to the edge of the disc be denoted by $(+a)$; then the disturbance simultaneously arriving from the next zone may be denoted by $(-b)$, since it must have started half a period earlier, when the disturbance in the plane of the disc was in an opposite direction. The disturbance simultaneously arriving from the third zone may be denoted by $(+c)$, since it started a whole period earlier than the disturbance from the first zone, and in a complete period the disturbance in the plane of the disc changes back to its original character. Thus the disturbance D, due to all of the zones, may be written:—

$$D = a - b + c - d + e - f + g - \ldots (1)$$

It can be proved that the zones, drawn in the above manner, are equal in area; and hence it may be concluded that the numerical values a, b, c, etc., are nearly equal, decreasing slightly as we proceed along the series, if only on account of the increasing distances travelled by the corresponding wavelets.

We might sum up the series (1) in various ways. Since a is slightly greater than b, $(a-b)$ must be equal to a small positive quantity. Similarly $(c-d)$ is equal to a small positive quantity, and so on. Finally, the value of the whole series must be equal to the sum of a great number of small positive values, which at least shows that there will be *some* resultant disturbance at a point on the axis of

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the disc, and therefore in the centre of the geometrical shadow.

A more satisfactory way of dealing with (1) is suggested by the consideration, that the numerical value of any term is about midway between the preceding and succeeding terms; thus, the value of b is equal to the mean value of a and c, the value of d is equal to the mean value of c and e, and so on.

If we now throw (1) into the form,

$$D = \frac{a}{2} + \left(\frac{a+c}{2} - b\right) + \left(\frac{c+e}{2} - d\right) + \ldots . (2),$$

each term within brackets is approximately equal to zero, and

$$D = + \frac{a}{2};$$

or the resultant disturbance at a point on the axis of the disc is equal to half the disturbance arriving there from the half-period zone nearest to the disc.

Another point of importance may be noted. If we imagine the diameter of the disc to progressively diminish, the resultant disturbance is still equal to half that due to the first half-period zone. When the disc shrinks to a mathematical point, the first zone will be a circular space of approximately the same area as the zones previously dealt with. Thus if a^1 is equal to the disturbance from the central zone, the disturbance produced at the point on the axis of the disc would become equal to $\frac{a^1}{2}$ if the disc were removed; and since a^1 is nearly equal to a, it follows that the disturbance at the centre of the shadow of the disc is as great as if the disc were removed.

The above reasoning explains the cause of the disturbance at the centre of the shadow of a disc; and it is only in the immediate neighbourhood of this point that there is any appreciable disturbance. I cannot pretend that the above investigation is very rigorous, or even that a rigorous investigation could be carried out on the lines indicated. Up to the present it has been found impossible to determine, with mathematical precision, the nature of the disturbance at the various points within the shadow of a flat obstacle; even when, for simplicity, we suppose the obstacle to be an accurately circular disc, and the source of light or sound to be so distant that the waves near the disc are plane. But the simple result indicated is doubtless sufficient for practical purposes.

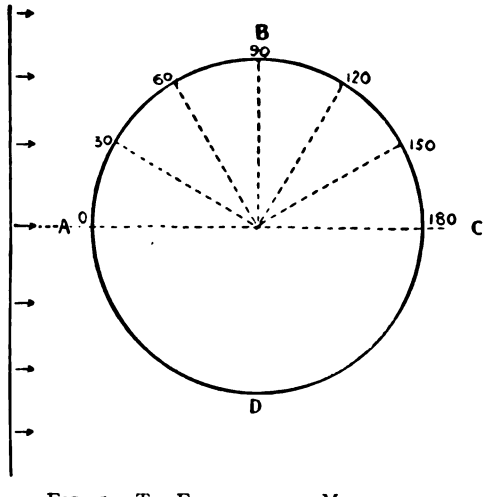

FIG. 5.—TO EXPLAIN THE MEANING OF THE CURVES IN FIG. 6.

To obtain the simplest mathematical conditions we may investigate the shadow of a *spherical* obstacle. If the sphere is small—comparable in magnitude with the length of the waves which throw the shadow—then we obtain a problem which admits of a complete solution.

It can be shown experimentally that there is sound at the centre of the acoustic shadow thrown from a small sphere, while at points removed from the centre of the shadow there is silence. To do this, a sphere is suspended so that its centre lies in the straight line joining the bird-call to the orifice of the pinhole burner; the only modification required in the arrangement illustrated in Fig. 4, is the replacement of the disc by a sphere. For the sphere, an ordinary ten-inch celestial globe, or on a smaller scale, a croquet ball, may be used. The sensitive flame flares when its orifice is situated at the centre of the shadow; the smallest displacement of the sphere causes the flame to recover, thus showing that it is only within a very small distance from the centre of the shadow that there is any appreciable sound.

I first observed this phenomenon when exploring the acoustic shadow of a sphere with the aid of a Helmholtz resonator and flexible tube applied to the ear. Such experiments are rather difficult to perform; they require some practice on the part of the observer, and they cannot be carried out in a room, owing to the multiple images of the source of sound formed by reflection at the walls. I therefore placed the source of sound in the open air, near the ground; and proceeding thus, I was able to detect sound at the centre of the shadow.

The difficulties to be overcome in the

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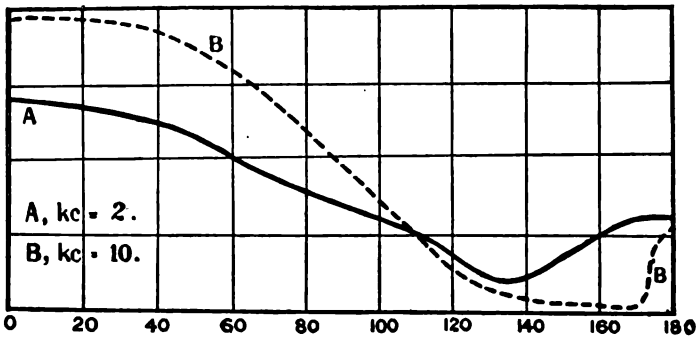

FIG. 6.—CURVES SHOWING THE INTENSITY OF SOUND AT VARIOUS POINTS ON A SPHERE, THE INCIDENT SOUND WAVES BEING PLANE, AND CONFINED TO ONE DIRECTION.

practical solution of the mathematical problem are very great; in the case of a large sphere (*e.g.*, a sphere of which the diameter is one hundred times as large as the wave-length of the sound), the problem is practically insoluble, owing to the difficulty of computing the numerical values of the expressions obtained. Let the ratio of the circumference of the sphere to the wave-length of the sound be denoted by kc; when kc is equal to 10, the circumference of the sphere is equal to 10 wave-lengths, and so on. The solution of the problem depends only on the value of kc, so that when obtained for a given sphere and a given wave-length, the results will apply to any other sphere of which the circumference is in the same proportion to the wave-length employed.

Let it be assumed that plane-waves travel up to a sphere in the direction indicated by the arrows in Fig. 5; the section of the sphere is represented by the circle A B C D. The waves first reach the point A, which may be termed the pole A. The position of any point on the sphere may be denoted by its angular distance from the point A; thus the point B is denoted by 90°, and lies on what may be termed the equator of the sphere. The anti-pole, opposite to A, is at 180°. The intensity of the sound at various points on the surface of the sphere is shown graphically in Fig. 6, in which curves for $kc = 10$ and $kc = 2$ are drawn. It will be noticed that the intensity of the sound falls off regularly as we proceed from the pole A toward the equator (90°). Beyond this position the intensity continues to fall off, until a minimum is reached at about 135° for $kc = 2$, or 170° for $kc = 10$. In both cases, however, the intensity of the sound ultimately increases as we approach the anti-pole (180°)—the point where we might naturally expect the intensity of the sound to be least.

I should have been unable to carry out, with any completeness, the calculations on which the curves in Fig. 6 are based, but that I was able to interest Professor Alfred Lodge in the subject. He has computed the tables of Legendre's functions necessary for the practical evaluation of the mathematical expressions.

In testing the results indicated graphically in Fig. 6, it is necessary to know the circumference of the sphere and the wave-length of the sound employed. The first of these magnitudes is easily measured directly, or calculated from the measured diameter of the sphere. The wave-length of the note emitted by the bird call is determined experimentally by the arrangement represented in Fig. 7.

The sound waves from the bird call are reflected normally from a plane surface, such as a sheet of glass. As a result, two trains of similar waves travel with equal velocities in opposite directions in front of the reflecting surface, thus forming stationary waves. At the reflecting surface, and at distances equal to 1, 2, 3, 4, ... half wave-lengths from it, there will be nodes, or points where the air is stationary. In the space between

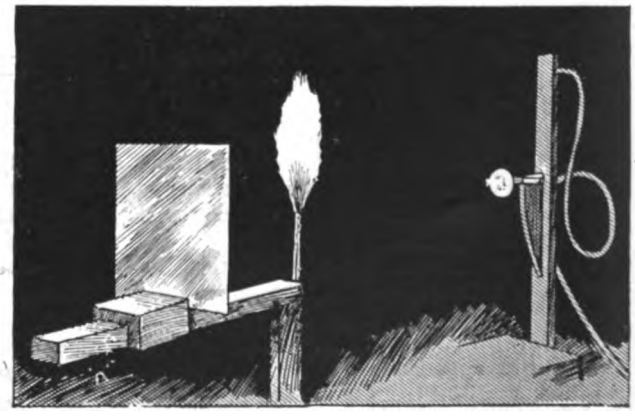

FIG. 7.—APPARATUS FOR DETERMINING THE WAVE-LENGTH OF A NOTE OF HIGH PITCH.

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any two consecutive nodes the air is in vibratory motion. The sensitive flame burns steadily when its orifice is situated at a node, but flares at points where the air is in motion. Thus we might measure the wave-length of the note by moving the sensitive flame away from the reflecting surface, counting the number of nodes passed through in a measured distance. It is preferable, however, to keep the flame stationary, and to move the reflecting surface. If we start with the surface at a point such that the flame burns steadily, we find that we must move the surface through 15 centimetres to reach the point where the flame recovers for the tenth time, so that 15 centimetres comprises 10 half wave-lengths, or the wave-length of the sound is equal to 3 centimetres.

Using the croquet ball, of which the circumference is equal to 30 centimetres, we have $kc = 10$; and the results represented by curve B (Fig. 6) may be tested. To satisfy the conditions assumed in the calculations, the point of observation should be taken upon the surface of the sphere. For various reasons this cannot be done; but we may take it fairly close, when we obtain a sufficient verification of the results represented graphically in Fig. 6.

My attention was recalled to this subject some time ago, in connection with the remarkable results obtained by Marconi in signalling across the Atlantic. Some hitch appears to have occurred in the transmission of messages, but without doubt signals have been transmitted across the Atlantic, and considering the difficulties standing in the way of such an achievement, the success obtained is truly remarkable. Moreover, this success is somewhat difficult to explain. Owing to the curvature of the earth, the sea rises nearly 150 miles above the straight line joining the transmitting station in Cornwall and the receiving station in Newfoundland: that this huge mass of matter does not cast a more perfect shadow than it appears to do is very surprising. The explanation is as yet unobtained; certain calculations which I have made tend to show that the success achieved may be mostly due to the extreme delicacy of the receiving apparatus.

In connection with the mathematical investigation which led to the results represented graphically in Fig. 6, there is a point of interest which I should like to mention. The investigation was carried out upon the supposition that the source of sound is at a considerable distance, so that the waves reaching the sphere are plane; and that the receiver, by which the sound is detected, is situated on the surface of the sphere. At any given position on the surface of the sphere, the receiver will indicate the reception of sound of a certain intensity, which may be read off from Fig. 6. Now the final results assume a form which shows that, if the positions of the source and the receiver are interchanged, the latter will indicate the reception of sound of the same intensity as in the original arrangement. Thus each of the curves in Fig. 6 represents the solution of two distinct problems: the intensity of the sound derived from a distant source and detected at any point on the surface of the sphere; and the intensity of the sound derived from a source on the surface of the sphere, and observed at a distant point. This result forms an interesting example of a principle of very wide application, which I have termed the *Principle of Reciprocity*. Some special cases were given many years ago by Helmholtz.

It is a matter of common observation that if one person can see another, either directly or by means of any number of reflections in mirrors, then the second person can equally well see the first. The same law applies to hearing, apparent exceptions being easily explained. Consider, for instance, the case of a lady sitting in a closed carriage, listening to a gentleman talking to her through the open window. If the street is noisy, the lady can hear what the gentleman says very much more distinctly than he can hear what she says. This is due to the fact that the gentleman's ears are assailed by noises of the street from which the lady's ears are shielded by the walls of the carriage.

Another instance may be mentioned, which will appeal to electricians. In the arrangement known as Wheatstone's bridge, resistances are joined in the form of a lozenge, a galvanometer being connected between two opposite angles of the lozenge, while a battery is connected between the other two angles. When the resistances are suitably adjusted, no current flows through the galvanometer; but a slight want of adjustment produces a deflection of the galvanometer, thus indicating the passage of a small current. Now, if the positions of the battery and the galvanometer are interchanged, the same current as before will flow through the galvanometer, and therefore, the deflection will be the same as before. Thus with a given cell, galvanometer, and set of resistances, the sensitiveness of the Wheatstone's bridge arrangement is the same whichever pair of

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opposite angles of the lozenge are joined by the galvanometer. If a source of alternating E.M.F. is used instead of the battery, and a telephone is substituted for the galvanometer, then the principle of reciprocity still applies, whether the resistances are inductive or non-inductive.

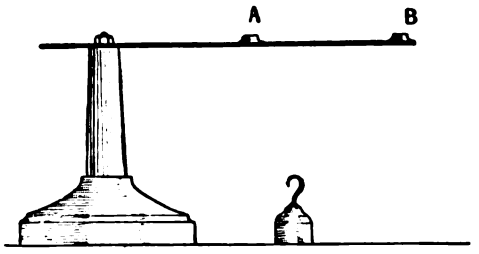

FIG. 8.—TO ILLUSTRATE A SIMPLE MECHANICAL APPLICATION OF THE PRINCIPLE OF RECIPROCITY.

A simple illustration, of a mechanical nature, is now shown. Fig. 8 represents a straightened piece of watch-spring clamped at one end to a firm support. A weight can be hung at either of the points A or B of the spring, when it may be observed that the deflection at B due to the suspension of the weight at A, is exactly equal to the deflection at A due to the suspension of the weight at B. This result is equally true wherever the points A and B may be situated; it applies not only to a loaded spring, which has been chosen as suitable for a simple lantern demonstration, but also to any sort of beam or girder.

It will have become clear, from what has been said, that waves encounter considerable difficulty in passing round the outside of a curved surface. I wish now to refer to a complementary phenomenon—the ease with which waves travel round the *inside* of a curved surface. This is the case of the whispering gallery, of which there is a good example in St. Paul's Cathedral. The late Sir George Airy considered that the effect could be explained as an instance of concentrated echo, the sound being concentrated by the curved walls, just as light may be brought to a focus by a concave mirror. From my own observations, made in St. Paul's Cathedral, I think that Airy's explanation is not the true one; for it is not necessary, in order to observe the effect, that the whisperer and the listener should occupy particular positions in the gallery. Any positions will do equally well. Again, whispering is heard more distinctly than ordinary conversation, especially if the whisperer's face is directed along the gallery in the direction of the listener. It is known that a whisper has less tendency to spread than the full spoken voice; thus a whisper, heard easily in front of the whisperer, is inaudible behind that person's head. These considerations led me to form a fairly satisfactory theory of the whispering gallery, nearly twenty-five years ago.* The phenomenon may be illustrated experimentally by the small scale arrangement represented diagrammatically in Fig. 9. A strip of zinc about 2 feet wide, and 12 feet long, is bent into the form of a semicircle; this forms the model of the whispering gallery. The bird call B is adjusted so that it throws the sound tangentially against the inner surface of the zinc: it thus takes the place of the whisperer. The sensitive flame F takes the place of the listener. A flame is always more sensitive to sound reaching it in one direction than in others; the flame F is therefore adjusted so that it is sensitive to sounds leaving the gallery tangentially. The flaring of the flame shows that sound is reaching it: if an obstacle is interposed in the straight line F B the flame flares as before; but if a lath of wood W, which need not be more than 2 inches wide, is placed against the inner surface of the zinc, the flame recovers, showing that the sound has been intercepted. Thus the sound creeps round the inside surface of the zinc, and there is no disturbance except at points within a limited distance from that surface.

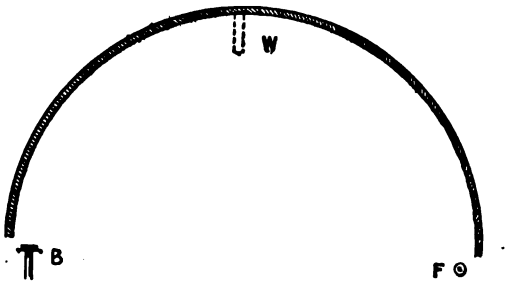

FIG. 9.—MODEL ILLUSTRATING THE PECULIARITIES OF A WHISPERING GALLERY.

Before concluding, I should like to say a word or two on a subject which, many years ago, led me to devise some of the experiments which I have already described: I mean binaural hearing.

Experiments on this subject may be easily carried out, but unless the conditions are carefully chosen, trustworthy results cannot be obtained. It would be as futile to experiment in a room, where the walls act as nearly perfect acoustic reflectors, as it would be to

* Theory of Sound.

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conduct optical experiments in an apartment with walls, floor, and ceiling covered with mirrors. Even in the open air we have the ground to reckon with. Experiments on binaural hearing may best be conducted on a lawn, one person being blindfolded, while others, occupying different positions, make various sounds: the blindfolded person attempts to point out the position from which each sound proceeds. When the human voice is used in its natural manner, there is no difficulty in locating the position of the speaker. When other sources of sound are used, difficulties arise. For instance, it is impossible to determine whether a tuning fork is sounded directly in front of, or directly behind the head. But when the fork is placed on one side of the head it is easy to decide its location with absolute certainty. It might reasonably be supposed that this decision is arrived at by noting which ear perceives the strongest sound; but evidence in support of this explanation is hard to come by. If one ear is closed, while the other is in turn directed toward, and away from the sound, very little difference can be noted. At present, however, there is no other explanation, and further discussion can scarcely prove profitable until more trustworthy experimental data have been obtained. Observations by experimenters deaf in one ear are especially valuable.

VECTORS AND GRAPHS AND THEIR PRACTICAL APPLICATIONS.

By ELLIS H. CRAPPER, M.I.E.E.

THE graphical treatment of many physical and engineering problems tends towards simplicity of solution, and is particularly neat, concise, and expressive. In the case of alternating current problems, graphical representations may be employed to exhibit magnitudes and phases, as well as direction; they thus possess the distinct advantage of appealing directly to the eye, and are particularly well adapted for indicating the relative variations of the various elements in alternating current working when two or more factors have to be taken into account. It is well recognised that graphical methods of treatment are valuable aids to obtaining a clear conception of the fundamental principles of the physical phenomena involved. They are not, however, perfect as means for making practical calculations, since the quantitative results have to be taken off to scale; and when the magnitudes of the various elements differ to a large extent it is difficult to obtain the requisite degree of accuracy. For this reason a new branch of mathematics, termed *vectorial algebra*, has been developed. This, taken in conjunction with the *symbolic* method of Steinmetz (a method introduced to simplify the analytical expression of directed quantities) enables us to take full advantage of the graphical treatment when dealing with periodic quantities.

Any quantity which may be completely represented by a line denoting (1) *direction*, (2) *magnitude*, and (3) *sense*, is termed a *vector quantity*, or simply a *vector* (*carrier*) or *directed quantity*. A vector is represented graphically by a straight line, and its magnitude is denoted by the number of units of length in the line, according to the scale chosen; the number of units being technically known as its *tensor*—a term introduced by Hamilton. The sense is usually indicated by an arrow-head. Displacements, velocities, forces, impulses, stresses, electric currents, electromotive forces and fluxes, all belong to the category of vectorial quantities, since they require something more than a number for their complete specification.

A *scalar quantity*, or simply a *scalar*, is one which possesses only magnitude, and is independent of direction. It is completely specified by a number. Mass, length, work, and power are scalar quantities.

The displacement of a small body from one point in space, through a determinate distance in a determinate direction to another point in space, is a vector. This gives one the idea that a vector is of the nature of a carrier, but it is often instructive to regard a vector as an *operator*.

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It is easy to see that the directed line A B (Fig. 1) of determinate length, completely represents a transference from one point, A, to another point, B. As the arrow-head denotes the sense, the order of the letters denoting the vector is clearly fixed. Usually, a vector is denoted by a single letter in the Clarendon type, or by two letters taken in proper order with a short horizontal line placed above them. Thus the vector A B (Fig. 1) is denoted by **a**, **A** or $\overline{A\,B}$. The position of a vector is completely specified by its length and sense, together with the angle which it makes with an axis, which may, for convenience, be chosen in an horizontal direction. A vector is positive when the order of the letters denoting the line is from left to right, whilst it is negative when the order is from right to left.

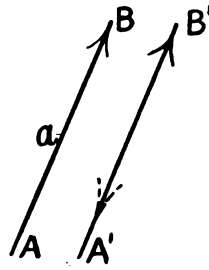

FIG. 1.

One vector is equal to another if both are parallel and of the same length (same scale being used) and have the same sense. Thus, $\overline{A\,B} = \overline{A^1B^1}$ (Fig. 1); and if A B represents a certain force or current, then A^1B^1 represents an equal force or current. When the sense is reversed the vector is negative, and if the arrow-head (shown dotted) were from B^1 to A^1, then

$$-\overline{B^1A^1} = \overline{A^1B^1} = \overline{A\,B}.$$

That is, the reversal of the sense of a vector quantity is denoted by multiplying the positive vector by -1, and

$$\overline{A\,B} + \overline{B^1A^1} = \overline{A\,B} - \overline{A^1B^1} = O$$

A localized vector—*i.e.*, a vector which occupies a definite position in space—has been termed by Clifford a *Rotor*; but in many cases a vector has not necessarily a definite or fixed position in space, and provided that the direction, magnitude, and sense of a vector be not changed, the vector may be moved parallel to itself. This fact implies that vectors which are coincident in direction may be placed so as to lie in the same line; such vectors are termed *like vectors*. *Like vectors*, therefore, are such as differ only in magnitude and sense.

Summation, or Composition of Vectors.—Vectors may be added or subtracted; for it is clear that if two vectors are arranged so that the end of the first coincides with the beginning of the second, then the vector which commences at the beginning of the first and terminates at the end of the second is the *sum* of the two vectors. Thus the sum of two vectors is equal to another vector which is equivalent to the two vectors in *effect*—*i.e.*, which will produce the same result as the two vectors superimposed simultaneously. This *vector sum* of two (or more) vectors is known as the *resultant* of the individual vectors, and the latter are termed the *components*. The *vector sum* is perfectly determinate in direction, magnitude, and sense.

PROBLEM 1.—To determine the sum of the two vectors **p** and **q**, given in Fig. 2.

From O draw the two lines O P and O Q parallel and equal to the vectors **p** and **q** respectively, and complete the parallelogram O P R Q. Draw the diagonal O R; then O P and O Q are the two given vectors, and O R is their vector sum. Since a vector is of the nature of an operator, it is obvious that if $\overline{O\,P}$ and $\overline{O\,Q}$ represent two forces acting simultaneously upon a small body at O, then by considering the effect of each upon the body, $\overline{O\,P}$ alone would carry the body from O to P, and if $\overline{O\,Q}$ be then introduced, the body will be transferred from P to R along P R. But it is equally obvious that a force represented by O R would also take the body from O to R, and since O R is a straight line perfectly determinate in direction, magnitude, and sense, $\overline{O\,R}$ is a vector which is equivalent to the joint effect of $\overline{O\,P}$ and $\overline{O\,Q}$, and consequently is the *resultant* or *vector sum* of the two vectors O P and O Q. Stated algebraically, we have—

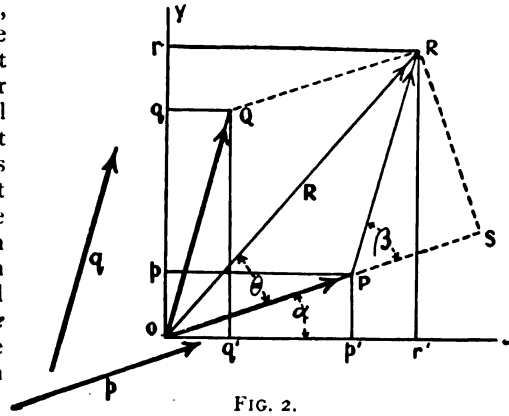

FIG. 2.

$$\overline{O\,R} = \overline{O\,P} + \overline{P\,R}$$

but $\overline{P\,R} = \overline{O\,Q}$

$$\therefore \overline{O\,R} = \overline{O\,P} + \overline{O\,Q}$$

and $\mathbf{R} = \mathbf{p} + \mathbf{q}$ if

$$\mathbf{R} = \overline{O\,R}. \quad (1)$$

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Corollary 1.—If two sides of a triangle represent, in magnitude, direction, and sense, two vectors taken in circuital order, then the third side of the triangle, in opposite circuital order, is the resultant of the first two vectors. This result is known as the *triangle of vectors.*

Corollary 2.—If two vectors are coincident in direction and sense, *i.e.*, if they are like vectors which have the same sense, their vector sum is equal in magnitude to the arithmetical *sum* of their *tensors.*

Corollary 3.—If two like vectors are opposite in sense—*i.e.*, if the angle between them is π or 180°—the vector sum is equal in magnitude to the *arithmetical difference* between their *tensors.*

Corollary 4.—The vector sum of n equal vectors is a like vector, the *tensor* of which is n times that of one of the components.

Corollary 5.—From the geometry of Fig. 2

$$\left.\begin{aligned} OR &= \sqrt{(\overline{OP})^2 + (\overline{OQ})^2 + 2 \cdot \overline{OP} \cdot \overline{OQ} \cos \beta} \\ \text{or } R &= \sqrt{\overline{p^2} + \overline{q^2} + 2\,\overline{p}\,\overline{q} \cos \beta} \end{aligned}\right\} (2)$$

And, if θ = the angle made by the resultant vector with the vector $\overline{OP}$

$$\tan \theta = \frac{RS}{\overline{OS}} = \frac{RS}{\overline{OP} + \overline{PS}} = \frac{\overline{OQ} \sin \beta}{\overline{OP} + \overline{OQ} \cos \beta} \quad (3)$$

From equation (2) it follows that the resultant vector is a maximum in magnitude when $\beta = 0°$—*i.e.*, when the two vectors are like vectors having the same sense, as stated in Corollary 2. When $\beta = 90°$

$$R = \sqrt{\overline{p^2} + \overline{q^2}}$$

Corollary 6.—The sum of the projections of two concurrent vectors upon an axis of reference, is equal to the projection of their resultant upon the same axis.

Let Oy (Fig. 2) be the axis of reference for the two vectors $\overline{OP}$ and $\overline{OQ}$, then Op and Oq are the projections of $\overline{OP}$ and $\overline{OQ}$ upon Oy; also Or is the projection of $\overline{OR}$ upon the same axis. Now, since PR is equal and parallel to OQ, pr = Oq, and the sum of the projections of OP and OQ is—

$$\begin{aligned} Op + Oq &= Op + pr \\ &= Or = \text{projection of } OR \end{aligned}$$

Exercises (1).—Two vectors, of magnitudes nine and twelve units, are perpendicular to one another; what is their vector sum? If the direction of the smaller vector is horizontal, what angle does the resultant make with this vector?

Answer: 15 units. 53° 4′-

(2).—Determine the vector sum of the above vectors when they are inclined to each other at 180°; 0°; and 60°.

Answers: [3 or − 3]; [21]; [17·11].

(3.)—A vessel sails eight miles to the eastward, and then six miles in a direction 60° north of east. Determine the distance from the starting-point, and the direction in which the vessel should have sailed in order to reach the same point in the most direct manner.

Answers: 12·16 miles and 25° 17′.

(4).—Two forces of twelve and five pounds weight act on a point, and their directions make an angle of 45° with each another. Determine their resultant.

Answer: 15·93 pounds-weight.

(*To be continued.*)

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USEFUL HINTS FOR STUDENTS OF COTTON SPINNING.

By J. H. DAWSON.

Illustrated from Photo-micrographs specially taken for "Technics" by Edgar Senior.

THE student of cotton spinning often complains, and not without reason, that he is not supplied with reading matter as generously as he should be, considering the importance of the subject. This injustice is more glaring when we remember the rapid strides being made in the business by our foreign competitors, owing principally to the educational assistance they receive.

It is the intention of the writer to deal, as concisely as possible, with a few points that are likely to be generally useful to the student, especially during the coming examinations.

If the reader is attending some technical school, the teacher will probably have pointed out the importance of doing home lessons; this is a most important point: to be successful, the student should spend all the time he possibly can upon home lessons, and also upon the lessons which can be learnt during ordinary working hours. These latter consist principally of the reasoning out of problems which occasionally present themselves for solution. Whenever such a problem presents itself, let it not be banished from thought as a nuisance, but stick at it until it has been solved. When a difficulty arises, do not be afraid to ask questions. Surely someone amongst your numerous friends and acquaintances will be able and willing to help you. If not, then save the problem until class night, have it neatly written out, and hand it to your teacher with a request that he will provide you with the solution. This "self-help" is indispensable to success: it gives the student the habit

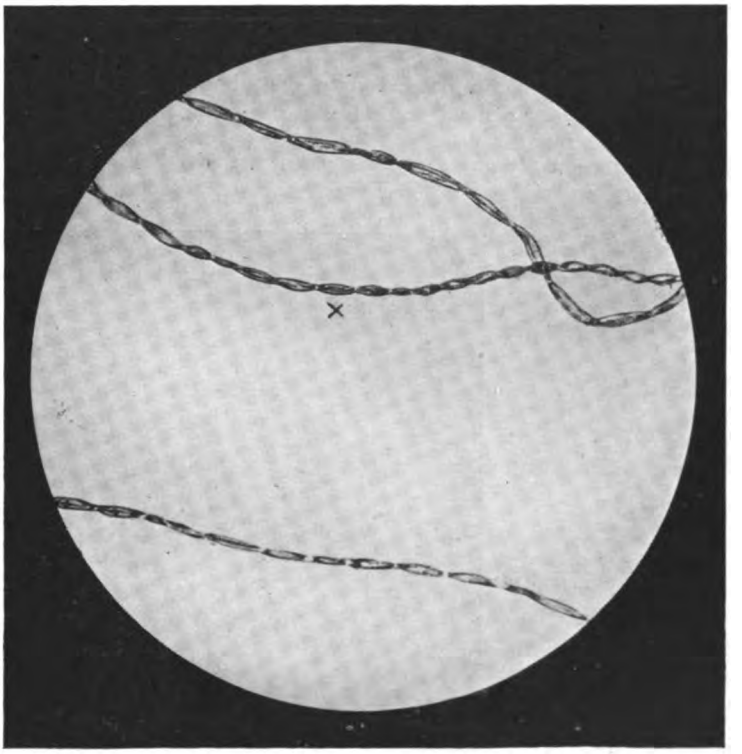

FIG. 1.—PHOTO-MICROGRAPH OF RIPE COTTON FIBRES, SHOWING TWISTED STRUCTURE. MAGNIFIED 200 DIAMETERS.

FIG. 2.—ENLARGED VIEW OF FIBRE LYING NEAR X IN FIG. 1.

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of reasoning out things for himself, a habit which is more beneficial to him on an examination night than perhaps he is aware, and even more so when it is accompanied by

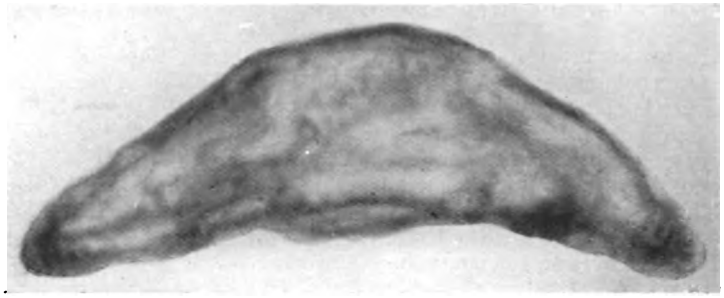

FIG. 3.—PHOTO-MICROGRAPH OF TRANSVERSE SECTION OF RIPE COTTON FIBRE. MAGNIFIED 2,700 DIAMETERS.

the self-reliance which the above system of "independent research" instils into him.

There is nothing in cotton spinning but what can be thoroughly mastered and understood by a determined student. There are no mysteries, nor is there any effect the cause of which is not ascertainable. Every separate process starts with a definite object in view, and the means used in order to attain this object consist of the simplest mechanical devices that can possibly be adopted.

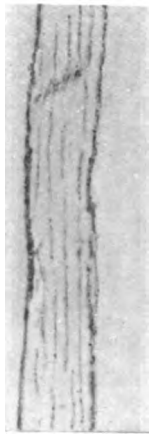

FIG. 5.—ENLARGED VIEW OF DEAD FIBRE LYING NEAR X IN FIG. 4.

To obtain a thorough understanding of the structure of the cotton fibre is the first step; and by spending a little extra time and study upon this feature, the student will be amply repaid, as he will be enabled to understand some of the later lessons much better. To know, and remember, that the fibre is coated with wax, will open up several channels of thought. This will explain the fact, that when the weather is very dry, and especially during dry east winds, the fibres curl upon themselves and fly away in all directions, owing to the electric

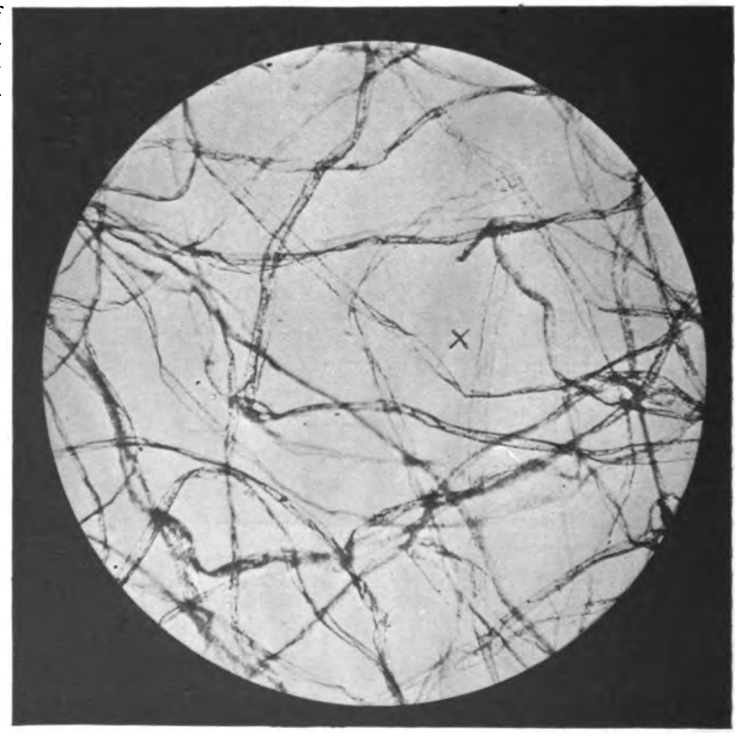

FIG. 4.—PHOTO-MICROGRAPH OF DEAD COTTON FIBRES. MAGNIFIED 200 DIAMETERS.

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charges produced while they were being "drawn" in the several processes; this disturbance being caused by the friction between the waxy surfaces of the fibres. The method of avoiding this fault will suggest itself at once to the thoughtful student: viz., to remove the cause—the excessive dryness of the atmosphere. This is done by humidifying the air: artificially, by specially adapted machinery; and naturally, by sheltering the mill from east winds, and building in a moist situation.

FIG. 6.—PHOTO-MICROGRAPH OF TRANSVERSE SECTION OF DEAD COTTON FIBRE. MAGNIFIED 2,700 DIAMETERS.

characteristic, that the edges of the ribbon are thickened (Figs. 2 and 3) and that the fibre tapers to a point, which is solid; whilst at the base where it was attached to the seed, and throughout the greater portion of its length, the fibre is hollow. This will supply food for further thought.

The twistings and the thick edges are the qualities by which the fibres adapt themselves for spinning into yarns, owing to the manner in which they cling to, and interlock with each other; and the same features, combined with

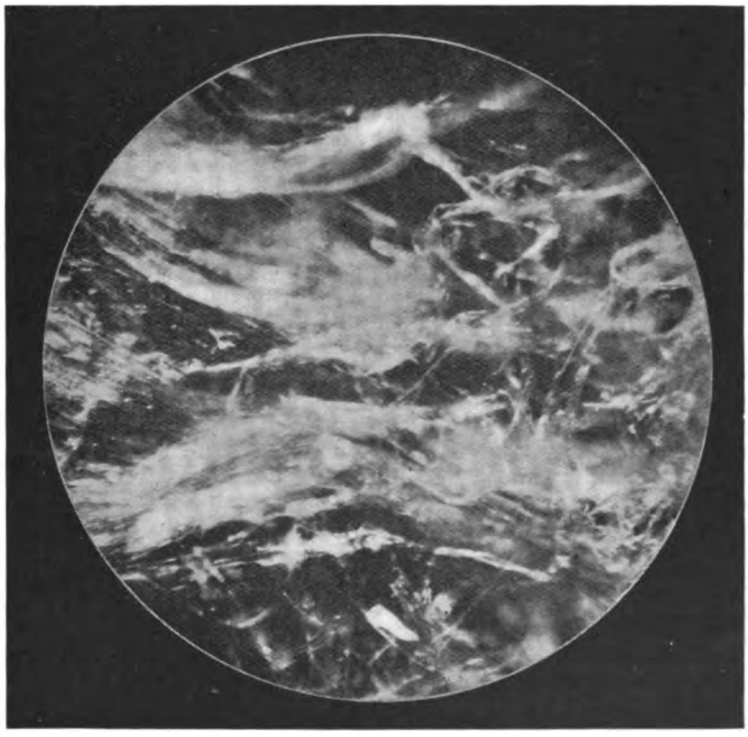

FIG. 7.—PHOTO-MICROGRAPH OF DEAD COTTON FIBRES, SHOWING THEIR GLASSY APPEARANCE AND STAINED PORTIONS. MAGNIFIED 65 DIAMETERS.

Remember also that the cotton fibre, when fully matured, appears twisted and ribbon-like (Figs. 1 and 2); but with this distinctive the hollow tube-like structural arrangement, is the reason why cotton fibres will take dyes, etc. It therefore follows that the more regular

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and frequent the twistings, and the more prominent the edges, the better the cotton will "grip" in spinning, and the stronger and more elastic will be the yarn produced. Also, the more pronounced the "bore," the better the dyes, etc., can penetrate.

Further, as the twistings of the fibre and the thickened edges are the effect of the same cause, viz., the withdrawal into the seed of the life-giving sap from the fibre during the ripening and opening of the "boll," it will also be clear that fibres gathered before they are fully ripe cannot possibly possess the characteristics described as being present in the ripe fibres, and therefore immature fibres are very objectionable when present in any quantity.

For more detail as to the botanical peculiarities of the fibre, the reader may consult one or other of the text-books on the subject. If a question were asked as to how you would determine when immature or unripe fibres were present in quantity in a bale of cotton, you might answer that the cotton would appear to the eye rather clean and free from leaf; if any leaf at all were present, it would be "green," the "feel" of the cotton would be slightly damp, and the "pull" weak and "gripless." The two principal trade descriptions for the above fault are "green" and "mossy."

The reason why unripe cotton appears clean and free from leaf is that, owing to the plant having failed to reach maturity, the leaves of the plant and the walls of the pod are fulfilling their natural functions, and, as a consequence, are firmly fixed on the stems, etc. If the cotton lint is stripped from the half-opened pods or bolls, without disturbing the leaves, the cotton will naturally appear clean, and any leaf present at all is bound to be green, seeing that the plant is in its green stage. Although expert pickers can take the cotton from the pod without breaking off the leaf when green, it is almost impossible for them to do it when the plant has reached maturity. At this stage the slightest touch will remove the leaves, which are then brown and brittle; consequently when dry brown leaf is present in cotton, it follows that the cotton is mature.

The extreme opposite to unripe fibre is dead fibre. When this is present in any quantity it is as bad as, if not worse than, the unripe cotton. To identify this class of fibre, the student has simply to reason the matter out as advised in the earlier portion of this article. Anything dead generally shrivels up, therefore dead cotton fibres must appear shrivelled up (Figs. 4, 5, and 6). Dead fibres are those that have been killed by some outside agency, either frost, drought, or the "boll weevil." Frost and drought will kill the cotton fibres just as they kill any other kind of vegetation; and the "weevil" causes similar destruction by depositing its eggs in the "bolls," and when the larvæ are hatched they feed upon the sap that ought to nourish the fibres. Dead fibres can be distinguished, when present, by the fact that they are bunched up together in small patches about the size of sixpenny pieces, and have a peculiar gloss (Fig. 7). There is a reason for this gloss which the student would do well to try and find out for himself. As a starting-point, I might remind him that a fibre of silk, when magnified, is like a glass rod.

When dead fibres are pulled between the fingers, they break off short, as if they had been scorched, which they really have; since owing to their being devoid of the requisite nutriment, the sun naturally scorches or shrivels them. When the boll weevil is responsible for the killing of the fibres, the latter have a further peculiarity, viz., they are generally stained (Fig. 7).

This stain is the so-called "boll stain" which, about a decade ago, was much discussed. Many writers attributed the "boll stain" to damp weather causing the endochrome, a colouring matter present in the seeds, to run and thus stain; but, as it can be proved that boll stain occurs in dry seasons, reason suggests some other cause. When the student considers that the "weevil" will pierce the seeds and partly destroy them in search of its food, and thus allow the endochrome to flow—in other words, cause the seeds to bleed—the stains can be understood.

I should like to close this article by pointing out to cotton spinning students how they can see the twistings of a cotton fibre with the naked eye. All text-books speak of microscopes, etc., which cost so much that they are outside even the dreams of the majority of students. Take a glass or cup full of water, place it near a window, and put a few fibres, half-a-dozen or so, upon the surface of the water, then move the position, either of the eye or the cup, until the light strikes the fibres at the proper angle, and you will see the "twists" quite clearly.

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ON THE DIAGRAMMATIC ILLUSTRATION OF CLASS LECTURES.

A Paper for all kinds of Teachers.

PART III.—THE LANTERN SLIDE.

By WILFRID J. LINEHAM, M.I.C.E., M.I.M.E., M.I.E.E.

THE phrase, "Infinite riches in a little room," originally applied to a library of books, may with even greater force be used in describing a collection of lantern slides. The lecturer, who has made a strong framework of illustrations by means of his blackboard and his paper diagrams, is always pleased to utilise the further illustration which the lantern slide affords; especially if, as in modern class work, the room can remain undarkened. It is, in fact, most important in class lectures to be able to change rapidly from one kind of illustration to another, and back again; and in this connection I may point out the importance of lighting the room electrically, where that is possible; for if the switches are placed immediately behind the lecturer, he can regulate the supply of light to suit any condition of illustration he may be using at the moment.

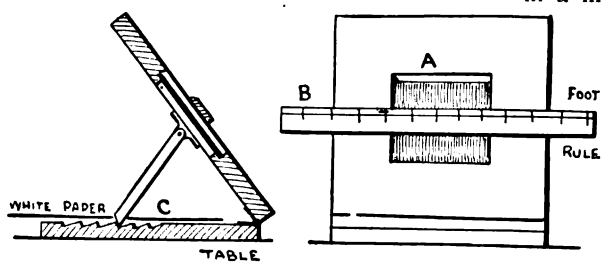

FIG. 1.—DRAWING DESK FOR SMOKE SLIDES.

Lantern slides may be produced either by photography or by hand, and it may surprise many readers to be told that hand-made slides are generally found to have a much higher value for class purposes than the products of the camera. This does not, of course, apply to particular cases, such as in microscopic work or where soft pictorial effects are required; but it is certainly true regarding all merely diagrammatic or line work. I shall, therefore, consider the subject of slide making under the headings of "hand-made" and "photographic" slides.

THE HAND-MADE SLIDE.

The very first question is the size of the slide: a question, however, in the answering of which one has all but no choice, for the importance of standardising the lantern slide occurred long ago to lantern manufacturers; and thus by a process of trial and error the present fixed size of $3\frac{1}{4}$ in. square was ultimately decided upon. I do not by any means wish to say that a larger slide can not be used, for Dr. Dallinger uses $3\frac{1}{2}$ ins. square for his beautiful pencil-made slides; but the objection is apparent—such slides are only permissible in specially built lanterns. The standard size of $3\frac{1}{4}$ ins. may then be accepted.

Smoke Slides.

Some ten years ago I commenced experiments in the making of hand-slides upon a smoked glass surface to be afterwards covered with a clear glass, the whole being mounted in a metal binding frame; but I found the smoke too delicate to withstand the touch of the cover glass, which caused the former to coagulate into blotches. I next tried the same slides with an intermediate air space, obtained by inserting a border of thick paper between the glasses, and found this entirely successful; so that many hundreds of such slides were soon afterwards prepared and are still in constant use with great success. The making of these slides I shall now describe.

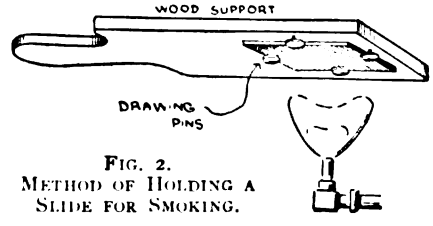

FIG. 2.
METHOD OF HOLDING A SLIDE FOR SMOKING.

Procure a support in the shape of a simple retouching desk (price 2*s.* 6*d.*) as in Fig. 1,

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in the square recess, A, of which the smoked glass is to be placed. A foot rule, B, is required as a hand-rest, as well as for ruling and measuring purposes. The glasses to be smoked are bought under the title of "cover glasses," and must be of the finest selected material procurable; one millimetre thick, and selling at 7*s.* per gross. Several kinds of holder were tried for the smoking process, but the original one shown in Fig. 2 had always to be returned to. This is merely a longish board supplied with a handle. To this the glass is loosely pinned, and the whole is passed to and fro over a bats-wing gas flame, first rather slowly lengthwise and then crosswise, about eight times one way and eight times the other. The exact number of times must be so found by trial; the resulting smoke on the glass must be darkish brown, but not black, when viewed by transmitted light. This condition should be ascertained once for all, because a rugged smoke is produced if a second coat be applied after cooling. Some four or six of these boards are required, to give time for cooling, and thus avoid keeping the slide-maker waiting. The reason for using the wooden support is, that by means of it heat may be retained long enough to allow the glass to cool slowly, and thus avoid breakage by sudden change of temperature; breakages frequently occur, as I found to my cost, when open framed supports are used.

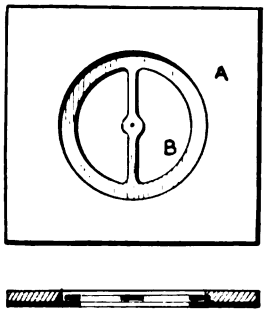

FIG. 3.
APPARATUS FOR CIRCLE-DRAWING ON SMOKE SLIDES.

The slide being removed to the retouching desk, a needle is next required for making the diagram. An ordinary steel crotchet needle, sharpened to a point, and having, as one knows, a bone handle, was the suggestion of a lady friend, and has ever since proved a satisfactory tool. Lastly, a sheet of white paper must be placed on the base of the desk at C, so as to reflect light through the slide, while at the same time a diffused light is permitted to play on the front of it, to enable the position of the needle to be seen. The diagram may now be made from any suitable copy, with the aid of the rule B for the straight lines, and freehand for the rest of the figure. Complete circles are somewhat difficult to obtain even by an expert, but these may be accomplished mechanically by means of the contrivance in Fig. 3, which consists of a wooden frame, A, having a thin brass ring, B, capable of turning in a circular groove. The ring is further provided with a bridge piece to take one leg of the compass, the other leg resting on the smoked surface; and in order to complete the whole circle the ring is slightly rotated within the groove.

The slide being fully drawn, it is to be covered and bound. Another glass is cleaned as a cover, and a border or packing of thin card, $\frac{1}{8}$ in. wide, is gummed all round the edge, as in Fig. 4. Next obtain one of Moore's metal binders, No. 161,070 (1*s.* per dozen), and having put the cover glass and smoke slide together, so that the smoked surface and packing strip are in contact, the pair of glasses are carefully placed within the metal binder, and the latter turned over at the edges with the fingers, the final flattening being given by rubbing an ivory penknife backward and forward over the metal with just so much pressure as not to break the glasses.

The making of a slide by the above procedure has taken some space to describe, though the actual process is really very rapid: two good diagrams in machine construction have been made in half-an-hour, from start to finish. The result upon the screen equals anything one could wish for. The picture can easily be seen on the lantern screen, if a good limelight be used, even though an ample supply of light be left in the room for the student's use; for it will be noted that the background of smoke is a perfect light absorber, while the lines of the picture are absolutely clear glass. Such results are unattainable by photographic means. An actual finished smoke slide has been reproduced in Fig. 5; this represents an ornamental gate made by the smithing class, and will show what a wealth of detail can readily be obtained in a very small

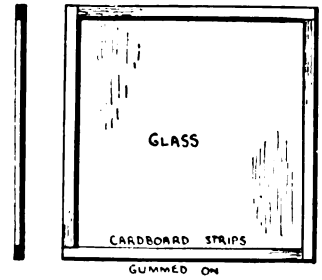

FIG. 4.
COVER-GLASS PREPARED FOR SMOKE SLIDE.

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FIG. 5.—FACSIMILE OF AN ACTUAL SMOKE SLIDE.

space; for although the glasses are $3\frac{1}{4}$ in. square, the border and margin leave only $2\frac{3}{4}$ in. in the middle of the plate for the actual picture.

Black Varnish Slides.

Despite the fact that I have been able to store a large quantity of smoke slides for regular use, and that they are quite safe in good hands, yet I am willing to admit that there are objections to this kind of slide. Careless workers grasp the slide at the centre, across the thickness, and the spring of the glass causes the two plates to touch, damaging the surfaces, though but slightly. Even so, I should have retained the smoke slide in the future, if I had not been introduced to a black varnish, which is, so far as I have tried, quite perfect. It is a spirit varnish prepared by A. Grothwell, of San Francisco, under the title of "preservative paint," and may be obtained from Mr. Penrose, 109, Farringdon Road. Its application to slides was the discovery of Mr. Wilkinson, the instructor of photography at the Goldsmiths' Institute, who very kindly supplied me with some coated glasses for experiment. The best way to apply the varnish is to pour it on the surface till completely spread, afterwards returning the superfluous portion. The colour obtained is a very dark brown, and the surface is so elastic that the needle marks may run quite close together without detaching the black altogether, as may be clearly seen from Fig. 6, where a quantity of written information is given upon an actual surface of this varnish. Of course, the picture is to be made upon the varnished plate in just the same manner as I have already described for the smoke slide, only that while the smoke slide cannot be erased or corrected, or even partially resmoked, without risk of breaking the glass, the line on the varnish slide may be "rubbed out" in places by covering with a little ivory-black in water-colour. In the binding, too, there is a distinct advantage, for any form of binder can be adopted, say, black paper, which is cheap, while the metal binder is decidedly expensive. Moreover, if one is in a hurry, a binder is not necessary

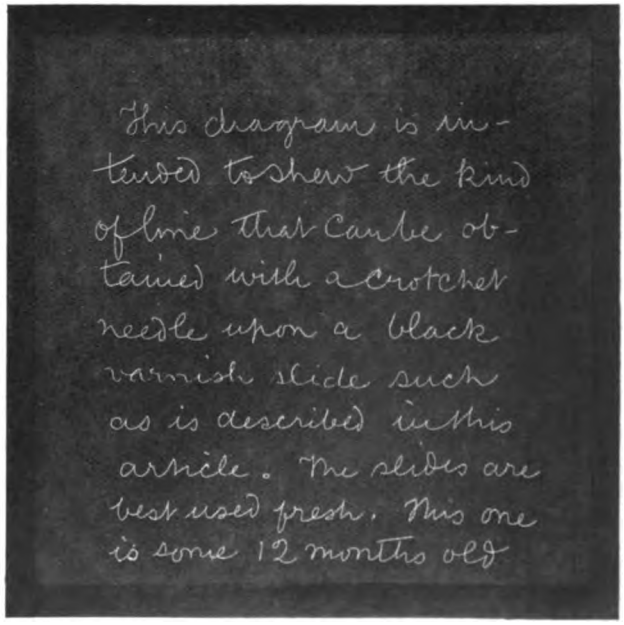
This diagram is intended to shew the kind of line that can be obtained with a crotchet needle upon a black varnish slide such as is described in this article. The slides are best used fresh. This one is some 12 months old

FIG. 6.—FACSIMILE OF AN ACTUAL BLACK VARNISH SLIDE.

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at all, the uncovered slide being placed directly in the lantern.

Ground-Glass Slides.

So far back as 1880 Dr. Dallinger described a process of making hand slides, which he has himself used more or less ever since with great advantage. Ground-glass

seen some of Dr. Dallinger's slides, which are certainly very fine and effective, though it is only fair to say they are the work of a most accomplished draughtsman. The reader must here be warned against the use of any material which is not as clear as glass itself, for the lantern light is quite unable to satisfactorily penetrate such materials as oiled

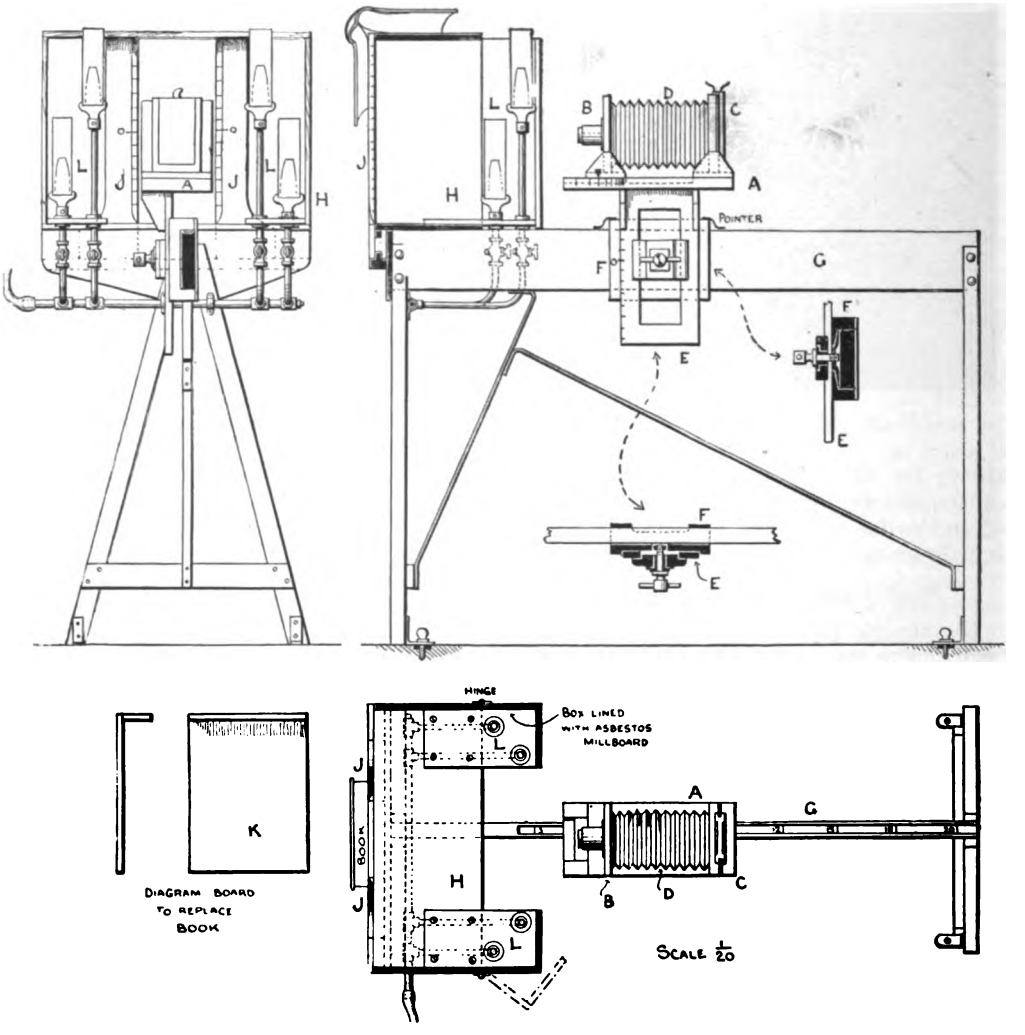

FIG. 7.—COPYING CAMERA FOR OBTAINING LANTERN SLIDE NEGATIVES.

plates $3\frac{1}{2}$ ins. square, having a very fine surface, were provided, and upon these the picture was drawn with a very hard and fine-pointed pencil. For better effect, the drawing was afterwards lightly tinted with various colours; and, lastly, the surface was coated with Canada balsam, which caused the glass to again become transparent. I have myself

paper or tracing paper of any kind.

THE PHOTOGRAPHIC SLIDE.

The making of a photographic slide is much more troublesome, and, what is worse, occupies a much greater time than the hand processes I have been describing. Still, if the whole of the photographic processes be

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reduced to a more or less mechanical system, there is no real difficulty in putting them into the hands of juniors, as I have myself found. I may be forgiven, then, if my descriptions appear a little long, in view of the importance of a careful account of the system. I shall first describe the working apparatus.

The copying camera, properly constructed, is an absolute necessity. To set up a stand camera and focus for every picture is far too great a labour, as well as giving poor results. Suitable copying cameras can be bought, but I preferred to build my own, to the design shown in Fig. 7. The design is not mine, but is due to my friend Prof. Pullen, of Chelsea: its construction can be carried out very inexpensively. The camera itself consists of a base-board A carrying front and back frames B and C, the former sliding and the latter fixed, while both are connected by two bellows D glued together so as to procure a long extension. The bellows can be obtained from Lancaster, of Birmingham: so can the lens, the two brass plates for the back frame (which serve as guides for the dark slides), and the slides themselves. Although the camera is built to quarter-plate size, I prefer to have a lens of half-plate capacity, so as to fully cover the picture without distortion. The lens may be a single-achromatic or group lens, and can, I believe, be procured for about fifteen shillings in its case, with screwed socket for fixing to the camera front.

The camera base is next secured to an upright board, E, sliding within vertical grooves, formed upon a saddle F; the board being further clamped at any convenient height, as shown. The saddle also may be moved backward or forward upon the main frame G, so as to place the camera at the required distance from the picture. As we sometimes have to photograph from a book, and sometimes from a paper fixed upon a board, a sort of proscenium or open box H must be constructed, having loose vertical boards J J to gauge and steady the picture. In the figure, a book is shown in position, for which a diagram board K may be substituted when required. The box just mentioned also serves to carry four incandescent gas-lamps LL, which give the best light one can have; for, although much heat is produced, the actinicity is excellent.

The first thing to do after constructing the camera is to gauge and graduate it for various-sized pictures. To do this, it is taken into the open air, so as to get the best light, and a good clear picture is fixed to the diagram board, preferably a large advertisement sheet from some engineering journal. Next place a plate of fine ground glass, upon which has been drawn in ink a central square of $2\frac{1}{4}$ ins. side, in the dark slide at back of the camera, so as to serve as a focussing screen. Also, squares are to be drawn upon the diagram of all sizes from $2\frac{3}{4}$ ins., or full size, up to the limits of the box. The camera being now moved backward or forward to various positions, and then focussed at each position, enables us to graduate the main frame with a scale figured for the size of picture that has been thus reduced to lantern-plate size. We must not forget to simultaneously graduate the positions of the camera board B, and when both are complete we have a means of adjusting the camera in position for any size of picture, without the aid of a focussing cloth. In addition to the backward and forward movements, the camera may also be raised till the vertical camera scale on E corresponds with another vertical scale J at the back of the box, thus permitting the centralising of the camera for any position of the diagram.

To take a picture upon a quarter-plate, so that it may afterwards be transferred to a lantern plate by direct contact, the sensitised plate is put into the dark slide in the dark room, and the slide afterwards put into the back frame of the camera. The diagram is next placed in position at S, and the camera adjusted for height by the vertical scales till it is level with the centre of the picture. The largest dimension of the latter having been measured in inches, the camera is moved horizontally along the frame till it coincides with the corresponding figure, and the front camera board is set to a like number. The lamps being fully alight, the dark slide is opened to the lens, and the latter uncovered for the proper time of exposure.

The Negative Plates.

The very finest results in the way of dense negatives (density being the chief desideratum in good line pictures), are undoubtedly obtained by the use of wet plates, but the process is too troublesome for amateurs. The next best results are obtained from that form of dry plate known as the "mechanical" or "process" plate, of which any good make may be used. I have adopted the Mawson mechanical plate, generally with excellent results, though with variation from time to time, which has induced me to think that they change much with keeping, and should there-

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fore be procured as fresh as possible. With the four lights to the camera, the time of exposure is not great, though the plates are slow: it varies from one minute as a minimum to two as a maximum. The worker should, however, ascertain the absolutely correct exposure for himself by photographing an average line picture in sections upon one plate. This is done by opening the slide to one quarter its height and exposing for half a minute: raising to half height with another half minute's exposure: another half minute at ¾ height: and a fourth half minute at full opening. By this means we have four exposures on the same plate, of ½, 1, 1½, and 2 minutes respectively. A normal development of the whole plate will at once show the correct exposure.

Developing the Negative.

The main processes of photography are known to most teachers, while even those who do not know may easily obtain the knowledge, so that it is not my intention in these short articles to do more than describe what I have found to serve my own particular purpose, without detailed explanation of the reason why. Nearly every photographer has his pet developing formula, and being no exception to the rule, I pin my faith to pyro-soda, and that only. I make it up in the following proportions:

5 oz. of sulphite of soda (crystals).

5 oz. of washing soda (in big pure lumps).

80 oz. of water (distilled not necessary).

This is really the 1 : 1 : 8 formula so well known, but as I use only one solution the quantity of water is doubled. To avoid continual trouble, I pound up the sodas by means of a rolling-pin and a suitable board, and store the powder in air-tight tins. If the water be heated in a kettle the solutions are quickly made. For several years I have used the pyrogallic acid in its dry form, feeling sure that I obtain better results thereby. The dry pyro I keep in a breakfast-cup in the dark room, and serve with a tea-spoon, only keeping open as much as I am likely to require at the time. I also provide a strong solution of either potassium bromide or ammonium bromide in a drop-bottle, about a quarter of the bottle being filled with salt and the rest with water.

The negative having been exposed, it is taken to the dark room and placed in a proper dish. I then make up a developing solution by putting one fluid ounce of the soda mixture in a measuring glass, adding half a teaspoonful of dry pyro, and eight drops of bromide. The amount of bromide is variable, but the above is a minimum. The developer is next poured on the plate in the dish, the latter rocked, and the developing carefully watched, the process being carried on till the white lines of the diagram are somewhat clouded over. The plate is then washed under the tap and transferred to the usual hyposulphite solution (a somewhat strong one) for fixing. When fixing is complete the plate is thoroughly washed in running water for half an hour, and dried spontaneously in a plate rack.

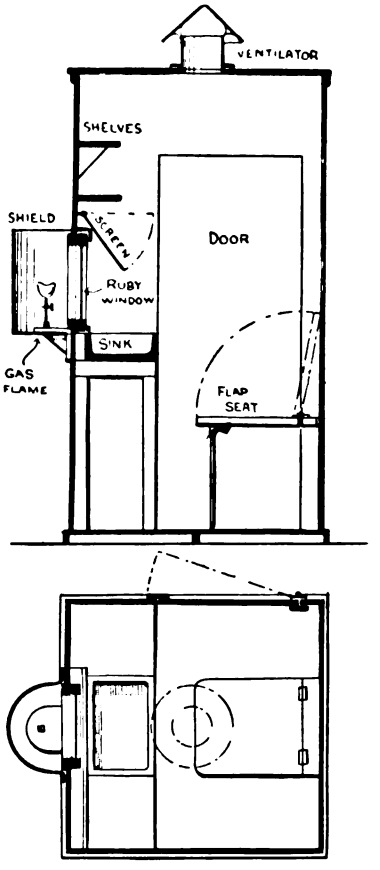

FIG. 8.
DARK ROOM FOR LANTERN-SLIDE MAKING.

If the print to be copied has good black lines on a bright white ground, the resulting negative will be a dense black that needs no further thickening; but if the film be not quite dense, the plate must be intensified, for it must be remembered that we intend to put the whole scheme in such mechanical train that a boy may do the printing.

Intensifying the Negative.

The most certain results are, I think, obtainable with the older form of intensifier. Make a saturated solution of mecury bichloride (corrosive sublimate) in one bottle, and a weak solution of ammonia in another. Do

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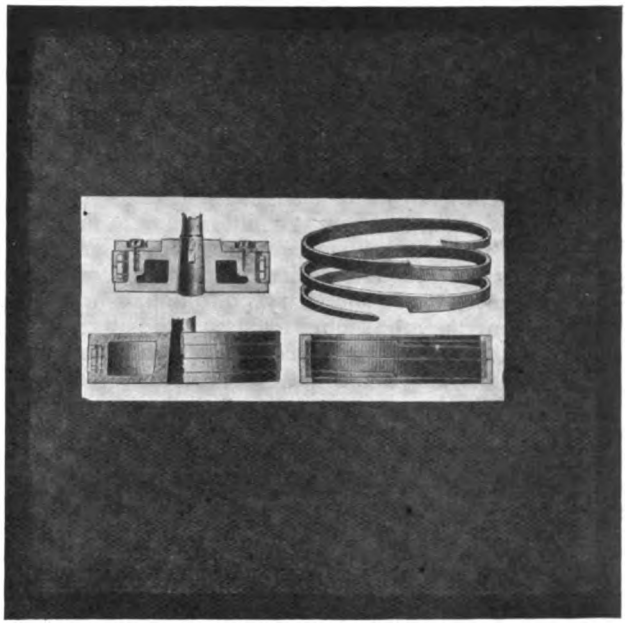
not trouble about the proportions of the latter, but above all keep the solutions well apart, and a separate dish for each solution. Having thoroughly washed the negative from hypo, put it in the mercury dish till it becomes white but dense, which will be in a few minutes. Again wash thoroughly. Next transfer to ammonia bath, when it will gradually become black and dense, requiring, say, five minutes for the change. Wash again for a few minutes and dry spontaneously. I need not say that it is better to do without intensification if possible, for the process is calculated to develop pin-holes in the film, as well as to cloud over the clear parts. The pin-holes should be painted out with water-colour ivory-black mixed with oxgall. Uranium intensification I do not favour, because the yellow colour makes it very difficult to gauge with accuracy the subsequent exposure necessary.

The Dark Room.

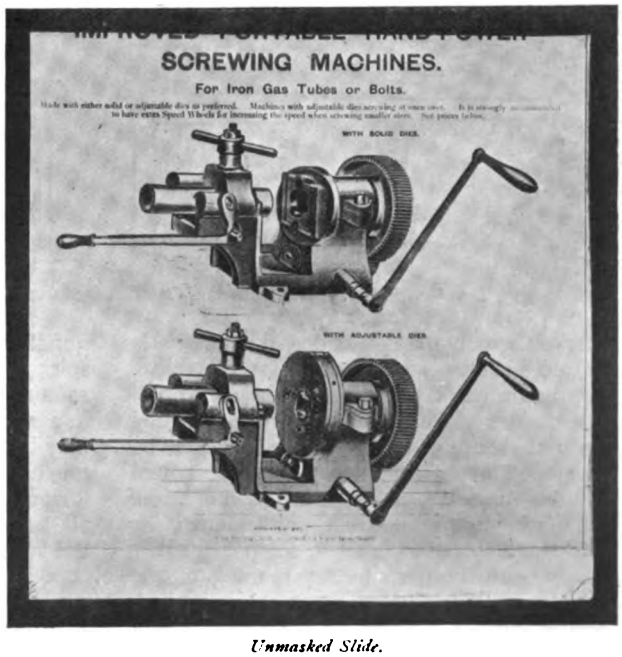
The dark room may be either a selected room in the building, or may be a wooden hut such as is advertised in the photographic papers at a cost of £3 or £4, and illustrated in Fig. 8. In either case I prefer to have a bats-wing gas-light placed outside the ruby-glass window, so as to keep the heat and fumes clear of the operator. The ruby window is placed just over the sink, and is capable of sliding to one side, so as to leave the white gas-light clear for exposures of slides. There should also be a ventilator in the roof.

Finishing the Negative.

To still further simplify the work with the object of putting the printing into the hands of juniors, it is often advisable to re-touch the negative, by painting out, with water-colour black or etcher's stopping-out varnish, all those parts that are not required in the final slide.



Masked Slide.



Unmasked Slide.

FIG. 9.—FACSIMILES OF MASKED AND UNMASKED SLIDES.

Printing and Developing the Slide or Positive.

The painting and development of the slides take place entirely in the dark room. I procure an ordinary half-plate printing

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frame, supplied with a plate of clear glass, and fasten to the inner surface thereof a mask of black paper having an opening 3 inches square. The negative is placed upon this glass, with film upward, and adjusted so that the square opening maps out the picture. Upon the negative comes next a sensitised lantern plate, by any good maker, so long as the glass is thin, and the two films being brought in contact, the frame is closed with the backboard. Turn the slide downward upon the table for a temporary protection, while opening the ruby shutter to admit white light, and then expose the slide vertically in front of the bats-wing burner and twelve inches away from it, for the space of a quarter minute if the negative be very dense, but less in other cases. It should be definitely understood that the directions here given have nothing to do with soft landscapes, but

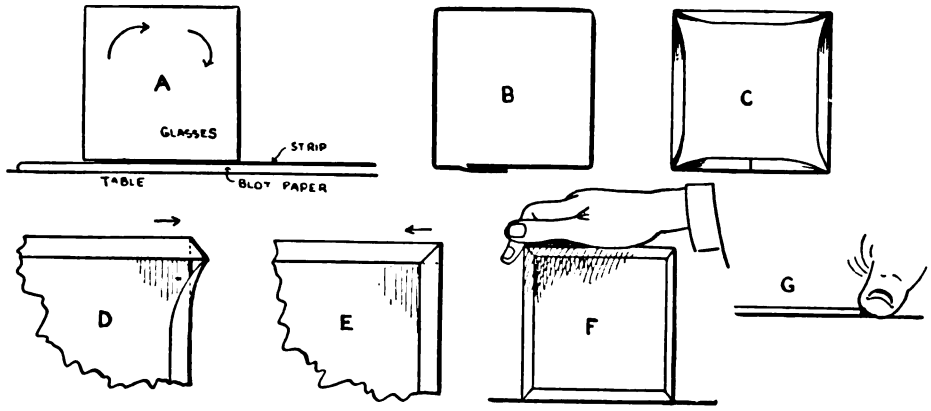

FIG. 10.—BINDING A LANTERN SLIDE WITH PAPER STRIP.

refer only to hard and strong diagrammatic effects, such as are required for class use. For the former the exposures should be half or a quarter of what I have given. Closing the red shutter, the slide is now to be developed in the same way as I described for the negative, using exactly the same solutions; this is a great convenience, for it is troublesome to have to keep a quantity of different bottles, to say nothing of the danger of using the wrong solution. Much greater care is needed in the development of the slide, however, and the bromide should not be spared. If the picture tends to flash out too rapidly, the exposure must be reduced at the next trial. It is highly important that the development should be slow, the picture not appearing if possible till one has had time to count twelve or twenty pretty slowly. If exposure be quite right, we watch the appearance of the picture most carefully, permitting the lines to become as black as ever we dare without there being the slightest appearance of a tint in the background. This is the most difficult part in the development of lantern slides, and the only way to achieve success is by a continual observation of the slides after they are dry. Suffice it to say that the picture (if a line diagram) must be as black as it can possibly be made, and yet when the slide is laid face downward on white paper, there should not be the slightest suggestion of a tint in the background; all must be quite clear glass. The development being stopped at the right time, the plate is very quickly rinsed under the tap, and dropped into the hypo bath: after fixing in this it is to be washed for half an hour and dried in a rack. This is the proper place to say that if negatives or slides are wanted quickly they may be soaked in methylated spirit for ten minutes, or better still, in a weak solution of formalin, and then dried as usual in a warm room. If formalin be used they may be dried at the fire. Above all, do not touch the film surface of the slide with the fingers during or after the drying process, for all such marks are afterwards visible upon the lantern screen.

Covering the Slide.

If the negative was not entirely blacked out in the background, some unsightly marks will be printed on the slide, and these must be masked with black paper, so as to shew nothing but the clean diagram. There is much to be said both for masked and for wholly clear slides. Blacking the negative saves the time of masking, which is important if more than one copy of the slide is wanted.

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Some people prefer the white margin to be reduced to its smallest limits, so as to avoid the distraction due to too much white light. In Fig. 9 I have placed two actual slides in juxtaposition: the one masked with strips of black paper, and the other shewing clear glass throughout: the reader is permitted to make his own choice. It is not necessary to gum the mask paper, but only to damp it, the gelatine of the film being a sufficient adhesive.

A cover glass having been cleaned and placed over the film, the binding must be done. Here we may choose between the metal slide previously described and the common binding strip of black paper. The former is best in unskilful hands, though there is often a little trouble with it in the lantern, for the binding strip is apt to turn up and catch in the carrier. But the paper binding is ever so much cheaper. Supposing some gummed binding strips to be procured, not too stiff in quality, the table is laid with a thick pad of blotting paper, and the strips are wetted on both sides, though not enough to remove the gum. The method of binding will be understood on reference to Fig. 10. Laying the strip on the blot paper as at A, with the gummed side uppermost, place the slide and cover-glass upon it standing upright, and rotate the latter in the direction of the arrow until the strip adheres to the edges only, meeting itself as at B. Next press the strip upon the glass surfaces, into the condition shown at C, leaving the corners untouched. Every corner is now separately treated by running the fingers in the direction of the arrow at D, and turning back as at E, till a clean mitre is made. Lastly, press the edges with the palm of the hand as at F; and, laying the glasses flat on the blot paper, smooth the binder firmly along the sharp edges with the fingers as at G. With a very little practice a perfectly neat method of binding is soon learnt: in fact, I have taught the method satisfactorily to quite young boys; and so quick does one become after a few trials that it is not difficult to bind sixty slides within half-an-hour, viz., one per half-minute. When the paper is quite dry the glasses may be cleaned of superfluous gum and the slide numbered.

(To be concluded.)

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THE PHOTOGRAPHIC IMAGE, IN THEORY AND PRACTICE.

PART II.

By EDGAR SENIOR.

IN carrying out experiments on the action of light on photographic compounds, or in the examination of bodies likely to be of use photographically, appeal must be made to the spectroscope. Not only the visible spectrum, but the invisible region beyond the violet must be considered, as most silver compounds, and in fact nearly all sensitive substances, are affected by ultra-violet rays. Those rays which cause a chemical change, either visible or invisible, are frequently *termed actinic*, all others being classed as *non-actinic*. The term actinic is rather misapplied, since from what has been stated it is evident that all rays are actinic under certain conditions, chiefly depending upon the sensitive compound employed. With one form of silver bromide discovered by Sir William Abney,* the whole of the spectrum, visible and invisible, is actinic, even into the infra-red region; so much so, that photographs of the carbon points in the electric arc were obtained through a sheet of ebonite, which only allowed rays below the red to be transmitted. Also under certain conditions it was found possible to prepare plates sensitive to very low radiations, such as those proceeding from boiling mercury or boiling water.

Infra-red Photography

In order to make an examination by means of the spectroscope, the substance we wish to examine is placed in the path of the light before it reaches the instrument, and the effect produced upon the spectrum is noted. Suppose, for instance, that a slab of fused silver chloride is employed; then there is no noticeable alteration in the visible spectrum. If the image of the spectrum is formed on a piece of card coated with quinine sulphate (a salt which becomes fluorescent under the action of ultra-violet rays) it is found that the ultra-violet rays are absent. On removing the slab of silver chloride, the quinine sulphate phosphoresces in the region of the spectrum beyond the violet, thus indicating the presence of ultra-violet rays. From this we gather that the silver salt absorbs the ultra-violet rays; and where absorption occurs we expect, on the theory that work is being performed, that some change will occur. This can be proved by placing a plate prepared with silver chloride in the spectrum, when on development it is found that the greatest deposit is produced on the part which was confined to the invisible ultra-violet rays. Thus, in an haloid salt of silver, the principal part of the energy absorbed does chemical work, and this work is due only to the rays absorbed. If a slab of fused silver bromide be examined in the same way as the chloride, it is found that the ultra-violet, the violet, the blue, and some of the green rays are absorbed; and on exposing a silver bromide plate to the spectrum, and subsequently developing it, a deposit will be formed in the corresponding regions.

Use of the Spectroscope

We now come to the question of the action of light on silver salts which have been treated with some of the dyes used in orthochromatic photography. Theory requires that chemical change shall only be effected by the rays of the spectrum which the body absorbs. Taking a typical case: eosin (one of the dyes used in colour sensitising of emulsions), when viewed in the spectrum, is found to absorb green rays. On exposing a plate coated with a mixture of this dye and an haloid salt of silver to the spectrum, it is found on development that a deposit of silver is formed on the part corresponding to the green region, as well as on the part corresponding to the region to which the silver haloid itself is sensitive. That portion of the spectrum, then, to which the dye may be expected to increase the sensitiveness of the silver salt, can be determined by examining the absorption spectrum of the dye itself.

Relation between Absorption and Chemical Action

It has sometimes been stated that the maximum photographic action does not coincide exactly with the locality of absorption, but that it is slightly shifted towards the red

* Phil. Trans., 1881.

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of the spectrum. This has been explained as probably due to a difference in the refractive index of the medium. Carefully conducted experiments, however, do not confirm this; and in fact, with proper precautions, the regions of absorption and chemical action are found to be coincident.

Owing to ultra-violet rays playing such an important part in photo-chemical action, it is often useful to be able to isolate them. Prof. R. W. Wood has recently published a method for making a screen which transmits only ultra-violet rays. He found that by combining a screen prepared with nitrosodimethyl-aniline

$$C_6H_4 \begin{cases} N\,O \\ N\,(CH_3)_2 \end{cases}$$

with cobalt glass, he obtained a screen which allows only ultra-violet rays to pass.

Owing to the minute chemical change effected by light upon silver salts in the production of camera images, the photographic action is an invisible one, and means must be employed to bring to the cognisance of our senses the alteration produced. This is technically known as development. In the Daguerreotype process the vapour of mercury is the developer, attaching itself to the portions altered by light; but whether from physical or chemical action is somewhat uncertain. Developers may be divided into two classes, distinguished by their mode of building up the image. In one case this is done from material external to the film, in the other from that within the film; the solutions being either acid or alkaline ones. Developers depend for their action on the affinity they have for oxygen; thus pyrogallol absorbs oxygen, rapidly becoming brown, more especially in an alkaline solution. Ferrous salts are converted into the ferric state, the changes being due to combination with more oxygen. If a solution of ferrous sulphate be added to one of silver nitrate, a reduction of the silver salt occurs, and may be represented chemically thus:

$$3AgNO_3 + 3FeSO_4 = 3Ag + Fe_2(SO_4)_3 + Fe(NO_3)_3.$$

This reaction is made use of in the development of wet collodion plates, and is typical of the methods in which the image is built up from matter external to the film. It

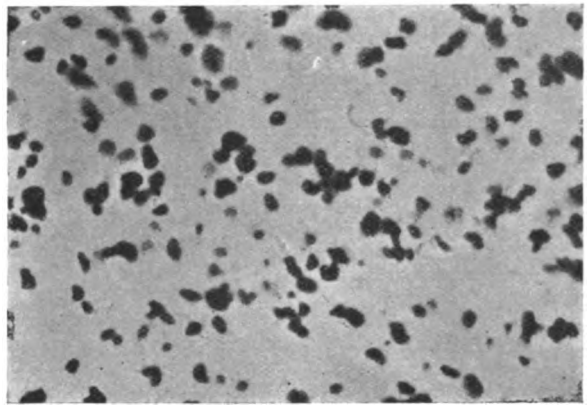

FIG. 5.—PHOTO-MICROGRAPH OF SECTION CUT PARALLEL TO THE SURFACE OF GELATINE NEGATIVE, SHOWING PARTICLES OF SILVER.
(*Magnified 1,200 diameters.*)

FIG. 6.—PHOTO-MICROGRAPH OF TRANSVERSE SECTION OF GELATINE NEGATIVE, SHOWING PARTICLES OF SILVER MOST DENSELY PACKED NEAR THE FREE SURFACE.

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FIG. 7.—PRINT FROM REVERSED NEGATIVE.

has been explained that the action of light is to produce a sub-salt of silver, and this class of development is based upon the theory that the sub-salt has an attraction for freshly-reduced metallic silver, which therefore becomes deposited upon those parts acted upon by light, so that an image is built up of varying quantities of deposited silver depending upon the different amounts of sub-salt produced by previous exposure.

In practice it is necessary to restrain the developer from too rapidly reducing the silver solution, otherwise a general reduction all over the film would occur. To this end the solution is acidified, which causes the silver to be deposited less rapidly. Acetic acid is generally employed on account of its mild restraining power, although nitric, sulphuric, citric, or almost any organic acid, may be used. Instead of acids, viscous substances such as glycerine are capable of producing physical restraint, and so causing the silver to be reduced more slowly.

With dry plates and plates which do not contain free silver nitrate, the method known as alkaline development is employed. Taking silver bromide as an example, the action of light on this is to form sub-bromide, and if an exposed plate is treated with a solution of pyrogallol made slightly alkaline with ammonia or other alkali, a blackening of the exposed parts takes place, and analysis proves that metallic silver has been formed. Now, experiment has shown that directly the silver sub-bromide is reduced to the metallic state, a combination is formed between the normal silver bromide and the metallic silver, producing silver sub-bromide :—

$$2\ Ag + 2\ Ag\ Br = 2\ Ag_2\ Br\ ;$$

this freshly formed sub-bromide is then reduced to the metallic state as before, and so the action continues until the image is fully developed. From this it is seen that the sub-salt is reduced by the alkaline developer in preference to the normal salt, or at any rate, more readily than the latter. This might be expected, considering that light has already removed part of the halogen; there is, therefore, less work for the developer to perform. The action of alkaline pyrogallol in developing an image cannot well be explained in an equation, but by taking an organic iron salt which acts in a similar way, such as ferrous oxalate, the change taking place can be more readily explained :—

Alkaline Developers

$$2\ Ag_2Br + 2\ FeC_2O_4 + K_2C_2O_4 = Fe_2\,(C_2\,O_4)_3 + 2\ K\ Br + 2\ Ag_2.$$

In development formulæ a soluble bromide,

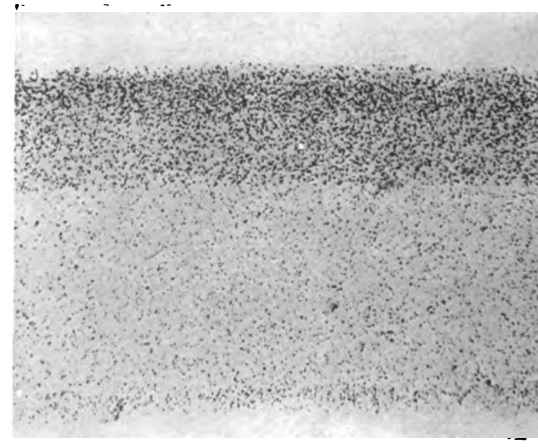

FIG. 8.—PHOTO-MICROGRAPH OF TRANSVERSE SECTION THROUGH A NEGATIVE ON A CRISTOID FILM, EXPOSED UNDER ORDINARY CONDITIONS.
(*Reproduced by kind permission of "Photography."*)

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such as that of potassium, usually figures; this is to check the formation of what is technically known as "fog," produced by the developer reducing the unaltered silver bromide, the soluble bromide apparently forming some compound which it is much more difficult for the developer to reduce.

Prevention of "fogging"

Microscopic examination, when properly conducted, reveals in a most striking manner many things connected with the formation of photographic images. The appearance of silver bromide in a gelatine plate has already been illustrated.* In Fig. 5 we have the appearance after development, the illustration being from a section cut parallel to the surface through the high lights of a negative. The black granules represent the silver forming the image. Fig. 6 is reproduced from a photo-micrograph of a transverse section through a gelatine negative, from which it is apparent that the greatest amount of silver is deposited at the upper surface of the film, the particles being much more scattered towards the glass.

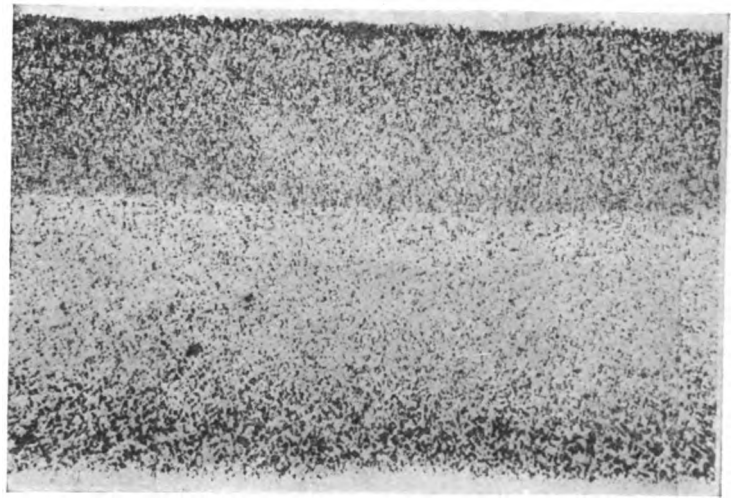

FIG. 9.—PHOTO-MICROGRAPH OF A TRANSVERSE SECTION THROUGH A NEGATIVE ON A CRISTOID FILM, SHOWING THE EFFECT OF AN EXPOSURE 660 TIMES THE NORMAL AMOUNT.
(Reproduced by kind permission of "Photography."

If, after development of the photographic image, the unaltered silver salts were left in the film, a print from the negative would be obtained with great difficulty, since the unaltered salts prevent the passage of light through the film almost as much as the reduced silver itself. The removal of the unaltered salts thus becomes a matter of necessity, and the requisite operation is known technically as "fixing." The substances employed depend for their action on the property of forming soluble double salts with the silver salts. At the same time, they must not be capable of readily attacking the silver image. With wet plates, potassium cyanide is very often used, and its action as a fixing agent is represented as follows:—

Fixing

FIG. 10.—FILAMENT OF ELECTRIC LAMP. PRINTED FROM A NEGATIVE ON A GELATINE PLATE TREATED WITH AN ACID SOLUTION OF POTASSIUM BICHROMATE.

$$Ag\,I + 2\,K\,Cy = K\,Ag\,Cy_2 + K\,I.$$

The same reaction occurs with the bromide or chloride. With gelatine plates, however, cyanide is not employed, owing to its slightly solvent action on finely-divided silver, which would injure the image. The substance which is used in its place is generally known under the name of hypo. This salt is a derivative of sodium sulphate, in which an atom of oxygen has been replaced by sulphur, producing what is known as a thio-sulphate, the prefix *thio* being derived from the Greek, and signifying sulphur: its derivation is shown in the following formulæ:—

Sodium sulphate.	Sodium thiosulphate.
$S\,O_2\begin{cases}O\,Na\\O\,Na\end{cases}$	$S\,O_2\begin{cases}S\,Na\\O\,Na\end{cases}$

If, to a solution of silver nitrate, sodium thio-sulphate be added in equivalent proportions,

* See the February number of "Technics," p. 190, Fig. 1.

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a white precipitate of silver thio-sulphate is formed. This rapidly changes colour, becoming finally black, due to the formation of silver sulphide :—

$$Ag_2 (S_2 O_3) + H_2 O = Ag_2 S + H_2 S O_4.$$

If, however, directly the silver thio-sulphate is formed, sodium thio-sulphate be added in considerable excess, the white precipitate dissolves, owing to the formation of a soluble double thio-sulphate of silver and sodium, in which the sodium salt is in excess. The change may be expressed thus :—

$$Ag_2 (S_2O_3) + 2\ Na_2S_2O_3 = Ag_2 (S_2O_3),\ 2\ Na_2S_2O_3$$

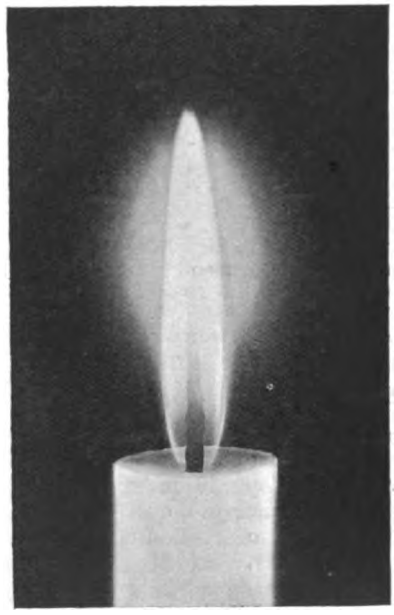

FIG. 11.—PHOTOGRAPH OF CANDLE FLAME, SHOWING EFFECTS OF HALATION.

If an haloid salt of silver be substituted for silver thio-sulphate, the same kind of change takes place :—

$$2\ Ag\ Br + 3\ Na_2S_2O_3 = 2\ Na\ Br + Ag_2 (S_2O_3),2\ Na_2S_2O_3$$

Therefore the operation technically known as "fixing the image" is due to the formation of a soluble double salt of silver and sodium.

We now come to a remarkable phenomenon sometimes met with, involving the partial or complete destruction of the photographic image. This is generally known as reversal, and is sometimes alluded to as solarisation. Reversal of the most complete kind means the formation of a positive instead of a negative on development: in Fig. 7 we have a good illustration of what is meant. As will be seen, the print is negative, and was made from a positive obtained direct in the camera. This leads one to consider the probable causes which operate to bring about results of this nature.

According to theory, the action of light liberates halogen from the silver salt, and this being set free in presence of organic matter (gelatine) most likely forms a substitution product with it, replacing either hydrogen or an hydroxyl group. The former, by com-

Reversal

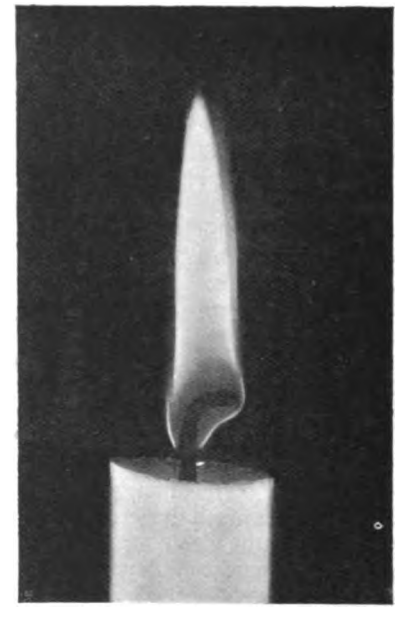

FIG. 12.—PHOTOGRAPH OF CANDLE FLAME, OBTAINED BY USE OF BACKED PLATE.

bination with bromine, would produce hydrobromic acid, which destroys the image so far as development is concerned; and the latter, by its well-known oxidising properties, would either oxidise the sub-bromide or the gelatine surrounding it, and thus render the image undevelopable. That something of this nature occurs would appear from the fact that in those parts of the plate which have received a strong action of light, the gelatine has become more insoluble than in the other portions. Then again, the bromine liberated lower down in the film may, in passing over the sub-bromide first formed, reconvert it to normal bromide, and this hypothesis is borne out by reversal taking

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place at the top of the film and not at the bottom.

This, then, may be taken as an explanation; and if a plate be soaked in a strong bromine absorbent such as sodium-sulphite or potassium nitrite, even with very prolonged exposure reversal would be practically absent. There is also a greater liability to reversal if any soluble haloid remains in the film, this being sensitive to light itself, and undoing the work performed on the silver salt. When a glass plate forms the support for the emulsion, reversal is of a much more pronounced character than when paper or some other pervious support is used; this is probably due to there being two surfaces from which bromine can escape. In the illustrations (Figs. 8 and 9) we have examples of a normal, and a prolonged exposure on a cristoid film. Fig. 9 shows the result of an excessive exposure (660 times the normal) which has produced strong action through the entire film, but in the middle part of the film there appears to have been a partial destruction of the image. As the result of experiments regarding reversal, it is stated by Dr. Eder, that if a plate be soaked in an acid solution of potassium bichromate, an exposure that would give a positive by ordinary development will yield a negative. The writer tried this method, with the result shown in Fig. 10. As will be seen, the only image obtained was that of the filament of the lamp.

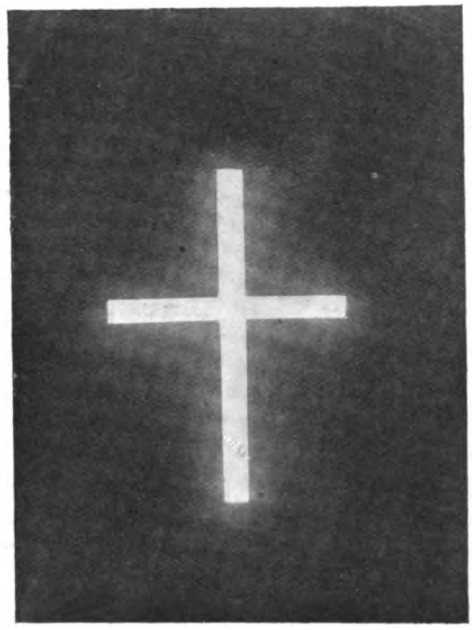

Fig. 13.—Photograph of Cross, showing Effects of Halation.

Another phenomenon met with in photography is halation, or blurring of the image—an encroachment of the high lights on the darker portions adjacent to them. This is well illustrated in Fig. 11. Halation is really caused by reflection from the back of the glass plate, as well as by the scattering of light from the particles of silver salt: the more transparent a film is, the less pronounced this blurring becomes. The intensity of the halation will depend upon the angle at which the rays of light are reflected, being greatest at the critical angle of the glass.

Halation

Halation can be studied by photographing figures cut in tinfoil or thin black paper, as in Fig. 13, where the form taken by the halation resolves itself into a series of rings. This phenomenon being principally brought about by reflection from the back of the glass, it can be done away with, or, at all events, lessened, by applying something to the back of the glass which will prevent reflection, or which will absorb the chemically active rays. In order to be effective, the material employed must be in optical contact with the glass, and should also possess as nearly as possible the same index of refraction as the glass for the light which has to be absorbed. The substance which answers this purpose the best is probably asphaltum. Collodion stained with an orange dye, or orange paper gummed to the glass, will also be effective with ordinary plates, but with orthochromatic plates, especially those sensitive to red, a black backing is necessary. In any case, a backing, when properly applied and suitably selected, will be found to remedy this objectionable appearance in photographs, as is shown in Fig. 12.

Backing

It is often noticeable that reversal of an image appears exaggerated when halation is present, this being due to the latter forming a background on which the reversal can be more readily seen, the time necessary to cause reversal of the halation being much eater than that required to reverse the actual image, owing to the weaker intensity of the reflected light.

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THE CONTINUOUS-CURRENT DYNAMO.

PART III.

By H. M. HOBART, M.Inst.E.E.

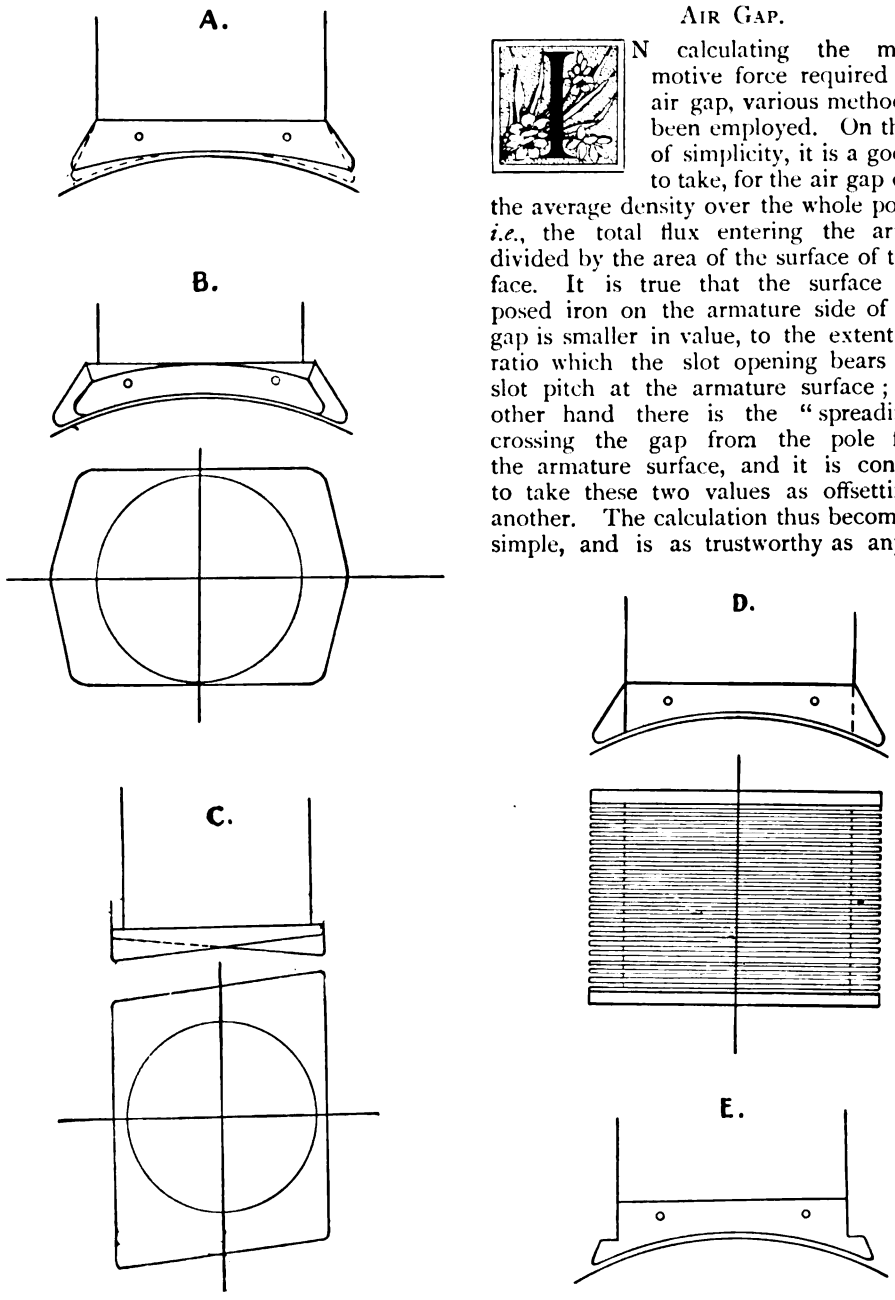

FIG. 22.—EXAMPLES OF SPECIALLY-SHAPED POLE SHOES.

AIR GAP.

IN calculating the magneto-motive force required by the air gap, various methods have been employed. On the score of simplicity, it is a good plan to take, for the air gap density, the average density over the whole pole face, *i.e.*, the total flux entering the armature, divided by the area of the surface of the pole face. It is true that the surface of exposed iron on the armature side of the air gap is smaller in value, to the extent of the ratio which the slot opening bears to the slot pitch at the armature surface; on the other hand there is the "spreading" in crossing the gap from the pole face to the armature surface, and it is convenient to take these two values as offsetting one another. The calculation thus becomes very simple, and is as trustworthy as any more

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complicated method. In the case under consideration we have—

Area of pole face = 40 × 61 = 2,440 sq. cms.

Average pole face density = $\frac{21,800,000}{2,440}$

= 8,900 lines per sq. cm.

In text-books treating of the fundamental principles of electricity and magnetism,* one finds the formula—

$$H = \frac{4\pi n C}{10 l}, \text{ or } \frac{n C}{l} = \frac{10 H}{4\pi} = 0{\cdot}8\ H$$

where H is the magnetomotive force, in c.g.s. units, which for a material of unit permeability, is also equal to the flux density in lines per square centimeter; and where n is the number of turns, C the current in amperes, and l the length of the magnetic circuit.

But in dynamo calculations it is more convenient to express the magnetomotive force in terms of the "ampere-turns," first obtaining the "ampere-turns per centimeter of length," and afterwards, by multiplication with the length concerned, obtaining the total ampere-turns. Since air is of unit permeability, we have for the air gap,

H = Average pole face density.

$\therefore \frac{n C}{l}$ = 0·8 × Average pole face density.

l = length of air gap in centimeters,

$\therefore n C$ = 0·8 × Average pole face density × length of air gap in centimeters.

The length of air gap is in this case (the 400 k.-w. dynamo) equal to 0·9 cms.

Magnetomotive force per spool, for gap = 0·8 × 8,900 × 0·9 = 6,400 ampere-turns.

Many designers prefer to "chamfer" and otherwise specially shape the pole face, with a view to grading the "magnetic fringe" and improving commutation. This is a troublesome and generally ineffective procedure. Others "skew" the pole shoes to accomplish the same result. It is much better, as will be subsequently more particularly explained, to design for such low reactance voltage as to render such expedients unnecessary. Even for speeds and outputs where sufficiently low reactance voltage per segment is impracticable, special shaping of the pole face is a most untrustworthy expedient. Examples of styles of such specially shaped, and of "skewed pole shoes" are given in Figs. 22A, 22B, 22C, and 22D. Where chamfering is used, it is convenient to determine by judgment an "equivalent" pole face area, and estimate the density from this and the minimum depth of air gap as a basis. In Fig. 22E the flux is throttled at the pole tips by virtue of their shape, and the result is equivalent to chamfering.

Pole Shoe.

The magnetomotive force for the pole shoe may be neglected, in virtue of its short length and in the interests of abbreviating the process of magnetic circuit estimation. This leads in practice to no appreciable inaccuracy, even where cast iron pole shoes are employed. Two forms of laminated pole shoe construction are given in Figs. 23A and 23B.

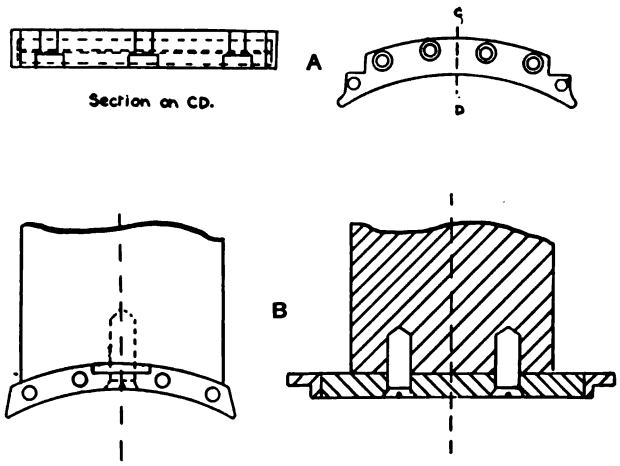

Fig. 23.—Examples of Laminated Pole Shoes.

Magnet Core and Yoke.

Magnet cores are, according to design, of cast steel, wrought iron forgings, sheet-iron or steel and cast iron.

Yokes are generally of cast iron or cast steel; occasionally of sheet-iron or steel. There is a close interdependency between the choice of materials for these two parts of the magnetic circuit. This relates chiefly to

* See, for instance, Dr. Thompson's "Elementary Lessons in Electricity and Magnetism." Macmillan & Co. London: 1897, p. 335.

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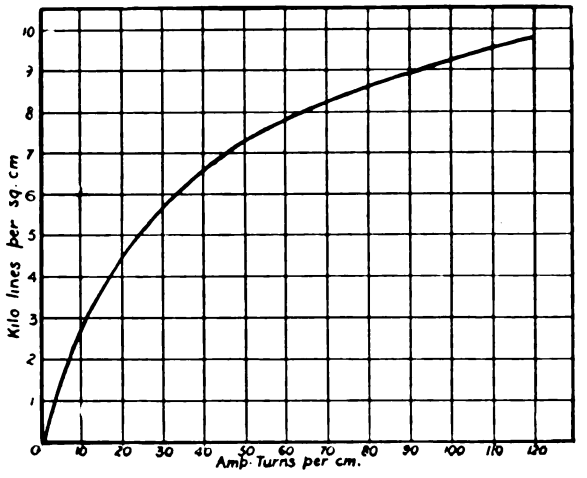

FIG. 24.—STANDARD MAGNETISATION CURVE FOR CAST IRON.

the relative permeabilities of these materials. Thus for magnetomotive forces up to 60

TABLE II.

Magneto-motive force in ampere-turns per centimeter.	Flux density in c. g. s. lines per square centimeter.		
	Wrought iron forgings and steel laminations.	Cast steel.	Cast iron.
20	15,500	13,000	4,500
40	16,700	15,000	6,600
60	17,000	16,500	7,900

ampere-turns per centimeter, which is a limit rarely approached in the magnet cores and yokes of continuous-current dynamos, we obtain the flux densities set forth in Table II.

These values correspond to the curves in Figs. 17, 24 and 25. Firms supplying magnetic irons and steels, almost invariably issue curves and guarantees corresponding to much higher values, and these are readily reproduced in test samples and in special cases. Nevertheless the designer cannot, at present, safely use more favourable curves than those given in Figs. 17, 24, and 25, unless he is in a position to be able to constantly test the materials received, check his results on samples and on completed machines, and to frequently incur the delay and loss consequent upon rejecting materials and reconstructing machines.

Probably the most economical construction consists in boring the yoke and securing the magnetic cores by bolts, as shown in Figs. 15 and 16 for the 400 kilowatt machine, and also in Fig. 21B, in which the pole shoe is in one casting with the magnet core. The joint was formerly generally made by abutting planed surfaces; but boring has been found to be distinctly cheaper, and is now the almost universal method. Were it not for the high density in the cast iron at the joint, yokes of cast iron would be preferable in cases where the increased weight constituted no objection for reasons concerned with transportation expenses; its advantage depending upon the greater rapidity of boring, and also on the greater rigidity of the structure, which would ensure more freedom from vibration. But the high density in the cast iron at the joint, prevents working the material of the magnet core at so high a density as would otherwise be employed. Thus in cast steel it is kept within 14,000 and 15,000 in large dynamos, and lower in small machines. But for this consideration, wrought iron forgings worked at about 16,000 would lead to economy, due to the decreased length of turn and decreased weight of copper in the magnet windings. Indeed, by the use of suitable percentages of aluminium or silicon, cast steel at these densities could probably be produced on a commercial scale, with as high

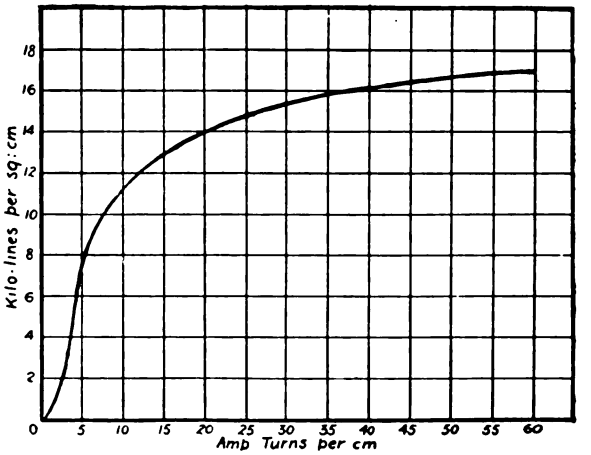

FIG. 25.—STANDARD MAGNETISATION CURVE FOR CAST STEEL.

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or still higher permeability.* To overcome the high reluctance at the joint, and thus to obtain these advantages, different constructions have been employed, though much less frequently than the construction shown in Figs. 15 and 16. Two of these are indicated in Figs. 26A and 26B.

Another type already shown in Fig. 21A and consisting of sheet-iron magnet cores cast into the cast iron yoke, does not possess the advantage of permitting high density in the magnet core, for this would lead to uneconomically high air-gap density. The type is nevertheless widely used, and with success; partly owing to the feature that the air delivered centrifugally from the armature ventilating ducts, finds more ready access to ducts between the magnet spools and the magnet core, thus permitting of economy in spool copper, in spite of the greater length of turn.

The diameter of the magnet cores of the 400 kilowatt dynamo is 45·5 centimeters, corresponding to a cross section of 1630 square centimeters.

To obtain the flux density in the magnet cores and yoke, we must take a total flux, not of 21·8 megalines—the magnitude of the flux entering the armature—but of 1·13 × 21·8 = 24·6 megalines.

The factor 1·13 was formerly known as the "leakage factor." Dr. Thompson (see p. 18 of "Dynamo Design") has substituted the term "dispersion co-efficient" to denote the ratio of total flux generated, to armature flux, and this is a more expressive term than "leakage factor," and should be employed. The matter is so well treated in other text books, that it will suffice to state here, that practical designers employ "dispersion co-efficients" of values which experience and judgment have led them to choose; and that they do not concern themselves much with the theory of the subject. Nevertheless, students and inexperienced designers will do well to consult the various sources of information on this subject, with a view to employing suitable values in their work. The values of the "dispersion co-efficients" generally found suitable in customary types of salient pole designs, range from 1·25 in small and crowded machines down to 1·10 in very large machines.†

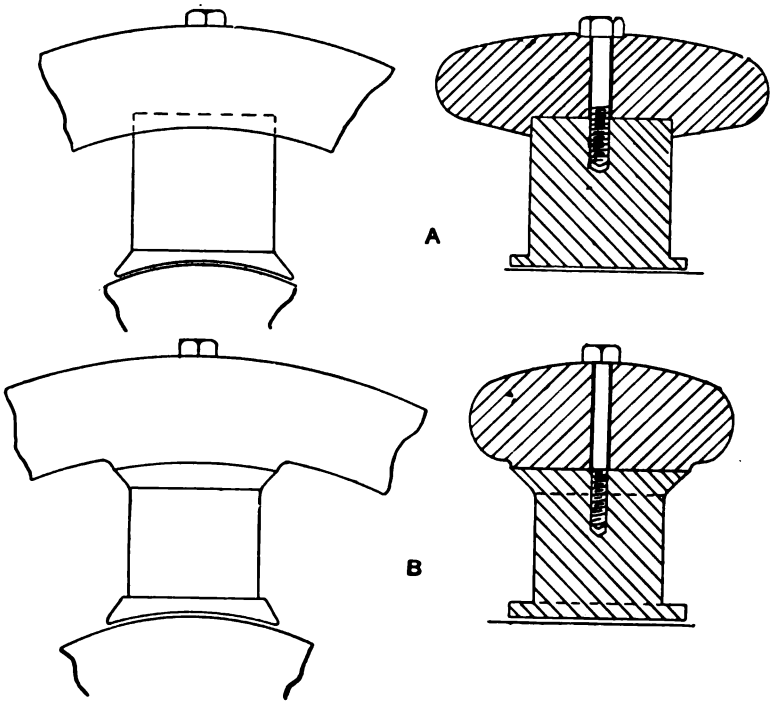

FIG. 26.—CONSTRUCTIONS USED TO MINIMISE RELUCTANCE OF JOINT BETWEEN YOKE AND CORE.

The flux density in the magnet cores of the 400 kilowatt machine is—

$$\frac{24{,}600{,}000}{1630} = 15{,}100 \text{ lines per sq. cm.}$$

From Fig. 16 we obtain a cross section of 2 × 1,386 = 2,772 square centimeters for the yoke, and a density of

$$\frac{24{,}600{,}000}{2772} = 9{,}000 \text{ lines per sq. cm.}$$

* See "The Electric and Magnetic Properties of Alloys of Iron," by W. F. Barrett, F.R.S., and W. Brown, B.Sc., "Technics," February, 1904, p. 123.

† Some test results for the dispersion co-efficient are given on p. 120 of "Electric Generators." See also p. 409 of "The Dynamo," by Hawkins & Wallace, 3rd edition, Whittaker & Co., 1903.

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The length of magnetic path (corresponding to one pole) in magnet core and yoke are

50 cms. for magnet core (including pole shoe), and $\left(\frac{145}{2} = \right)$ 73 cms. for yoke.

The ampere-turns per centimeter corresponding to the densities of 15,100 and 9,000, in these two parts of the magnetic circuit, are found from Fig. 25 to be 28 and 6 respectively.

Ampere-turns per spool for magnet core

$$= 50 \times 28 = 1{,}400.$$

Ampere-turns per spool for yoke

$$= 73 \times 6 = 440.$$

armature windings, and will not greatly decrease the total magnetic flux. This so-called "distorting" effect is greater the less the angular distance of the brushes from the mechanical neutral point.

The *direct* demagnetising effect of the armature winding when carrying current, may be very considerable, and is greater the more the brushes are displaced from the mechanical neutral point. This is an elementary point on which one might write at considerable length. It is of considerable importance to obtain a clear grasp of the conceptions involved. These are set forth from different standpoints in numerous treatises. It will suffice here to refer to the three diagrams in Figs. 27A, 27B, and 27C. These represent

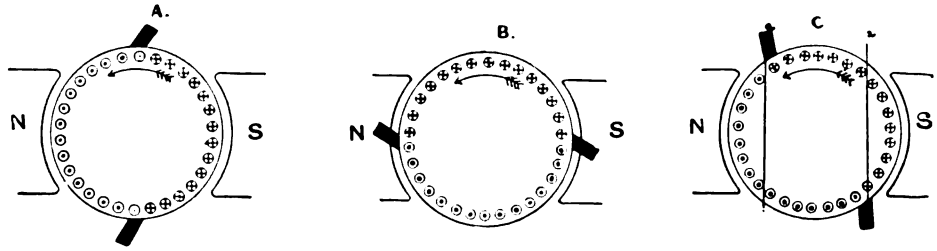

FIG. 27.—TO ILLUSTRATE THE MAGNETIC EFFECTS OF THE ARMATURE CURRENTS.

All of the component magnetomotive forces for 574 volts have now been estimated. They are as follows :—

AMPERE-TURNS PER SPOOL FOR 574 VOLTS AT NO LOAD.

Armature core below slots .	80
Armature teeth	2,100
Air gap	6,400
Magnet core	1,400
Yoke	440
Total	10,420

Thus 10,420 ampere-turns are found to be necessary for overcoming the reluctance of the magnetic circuit when traversed by a flux of 24·6 megalines in the frame and 21·8 megalines in the armature, on the assumption that the lines are evenly distributed over the respective component cross sections. But this will only be the case at no load. In proportion to the load carried by the armature, and to the position of the brushes, the flux will be distorted to a slight extent, and the density will be higher toward the forward side (referred to the direction of armature rotation) of the cross-sections. This is in virtue of the magnetomotive force of the

a drum armature in a bi-polar field, the brushes being set respectively in the geometrical neutral axis: opposite the middle of the pole faces; and in an intermediate position. Conductors carrying current flowing away from the observer are designated by circles containing crosses, and those carrying currents in the opposite direction, by circles containing points. It is seen that so far as the armature magnetomotive force is concerned, the magnetic poles coincide with the position of the brushes. Thus in the first diagram (Fig. 27A) the armature poles are at right angles (90°) from the centre line of the field-magnet poles, and there is no demagnetising component of the armature magnetomotive force, the effect being exclusively distortional. It is also evident that this distortional magnetomotive force acts on a magnetic circuit of high reluctance, and hence is very ineffective. In Fig. 27B, the armature magnetomotive force is exclusively demagnetising, and acts very effectively owing to the low reluctance of the magnetic circuit in this position. Fig. 27C is the intermediate case corresponding to prevailing practice. The importance of these effects is now coming to be much more generally understood, and a minimum brush displacement is often

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advocated. By careful design, this is generally practicable, and good low-speed dynamos may sometimes be operated with the brushes in the mechanical neutral position for all loads. This subject, however, can be better considered in the section relating to commutation. It is at present only necessary to consider the magnetomotive force aspects of the case. In Fig. 27c two vertical lines have been drawn through the points of contact of the two brushes. These define the demagnetising and distorting zones of conductors. Irrespective of how the face conductors are in reality interconnected, it is obvious that with relation to their position in space they may be paired off, as shown in Fig. 28, those connected from left to right exerting a distorting effect, while the remainder exert a demagnetising influence.

This places us in possession of a very definite analysis of the problem. It would at first sight be expected that the effect of the vertical ampere-turns of Fig. 28 could be off-set by auxiliary coils on the field poles excited with an equal number of ampere-turns. Experimental data show that this is not the case. The following may be taken as a rough working rule :—

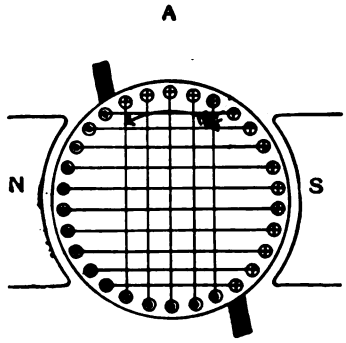

FIG. 28.—TO ILLUSTRATE THE GROUPING OF ARMATURE CONDUCTORS INTO "BACK-TURNS" AND "CROSS-TURNS."

Let P = the percentage of the polar pitch by which the brushes are set in advance of the neutral point.

Let T_a = armature turns per pole.

Let C = amperes per armature turn

Then $\frac{1{\cdot}75\ C\ P\ T_a}{100}$ = ampere-turns per field spool required to overcome the demagnetising component of the armature field.

For the 400 kilowatt dynamo, we have at full load

$$C = \frac{730}{8} = 91 \text{ amperes.}$$

$$T_a = 99$$

If the brushes are set 15 segments in advance of the geometrical neutral point, we have

$$P = \frac{15 \times 100}{99} = 15{\cdot}2$$

$$\frac{1{\cdot}75\ C\ P\ T_a}{100} = \frac{1{\cdot}75 \times 91 \times 15{\cdot}2 \times 99}{100}$$

= 2400 ampere-turns per field spool, required to overcome the demagnetising component of the armature field.

The co-efficient 1·75 requires explanation. It has been found by the analysis of many machines, that, on the average, a given magnetomotive force located directly in the armature conductors is, in virtue of its location directly at the point where the magnetic flux is required, 1·75 times as effective as a magnetomotive force located on the magnet core. The distortional component of the armature interference is greater, the less the brush lead. It is, however, very small in any case, and through the range of brush positions employed in practice, does not vary much with the brush position. It only slightly decreases the flux, through the increased densities occasioned by the unequal distribution of the magnetic flux over the cross-section of the magnetic circuit. It may be taken as independent of the brush position, and as requiring, to overcome its effect, an additional field magnetomotive force of

0·10 × total armature strength per pole.

In the 400 k.w. design, the total armature strength per pole is equal to 9,000 ampere-turns.

Hence the field magnetomotive force required to overcome the distorting component of the total armature interference is equal to

0·10 × 9,000 = 900 ampere turns.

Thus for 550 terminal volts at full load (574 internal volts) we must have per field pole

Saturation ampere-turns . .	=	10,420
Ampere-turns for overcoming armature demagnetisation .	=	2,400
Ampere-turns for overcoming armature distortion . . .	=	900
Total ampere-turns per field pole	=	13,720

At no load and 550 volts the last two components are not required, and the saturation ampere turns will be approximately

$$\frac{550}{574} \times 10{,}420 \times 0{\cdot}93 = 9{,}300 \text{ ampere-turns.}$$

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The factor 0·93 is taken as an approximate allowance for the bending of the no load saturation curve, and thus tedious calculations are avoided. In practice it is safer to recalculate the saturation values of 550 volts, in the manner in which they were calculated for 574 volts.

Now if the dynamo is required to automatically compound for 550 terminal volts for all loads from no load to full load, then

9,300 ampere-turns must be supplied by the shunt coil at all loads, and

13,720 − 9,300 = 4,420 ampere-turns must be supplied by the series coil at full load.

An explanation of the calculation of the field spool windings must be deferred to a later section, and it must be preceded by considerations of insulation and space factor.

(*To be continued.*)

THEORY OF STRUCTURAL DESIGN.

PART III.

By E. FIANDER ETCHELLS, A.M.I.Mech.E.

IN the second article a turning moment was defined as the measure of the tendency of a force to produce rotation around some axis. It is obvious that this tendency to rotation might be either in a clockwise or anti-clockwise direction, and the terms positive and negative were used to describe this difference in direction. The terms *plus* and *minus* are used as a matter of practical convenience, and because the terms are readily adaptable

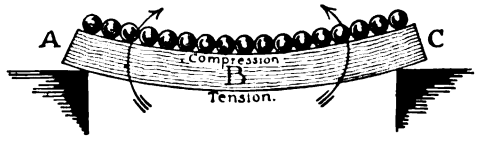

Fig 16

Positive Bending Moment

to an algebraical expression of the conditions of equilibrium. Otherwise, any other pair of terms of opposite significance would have served our purpose. In the case of beams, it has been the custom of the writer to take the forces on the left-hand side of any cross section, and if the resultant moment is in an upward or clockwise direction, to consider this as a positive bending moment. (See Fig. 16.)

If the resultant moment of the forces to the left of any cross section is in a downward direction it will then, of course, be taken as a negative moment. (See Fig. 17.)

In Fig. 16 let us fix our attention on the forces to the *right* of any cross section—between B and C, for example. The resultant moment is clearly in an anti-clockwise direction. Therefore we know that the external forces to the left of our section must be producing *a clockwise moment of equal magnitude.* So that, according to our definition, the bending moment in this case will be positive from one end of the beam to the other. This idea can be expressed in several ways. For instance, we might say that the bending moment is positive when the upper side of the beam is concave. Also by an inspection of Figs. 16 and 17 it will be apparent that a positive bending moment throws the upper fibres of the beam into compression, while a negative bending moment produces an elongation in the upper fibres.

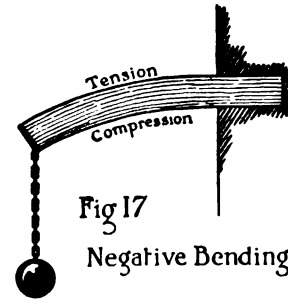

Fig 17

Negative Bending Moment.

The student will do well to carefully think over the ideas expressed in the preceding paragraphs, so that when he takes up any of the standard works on the subject he will

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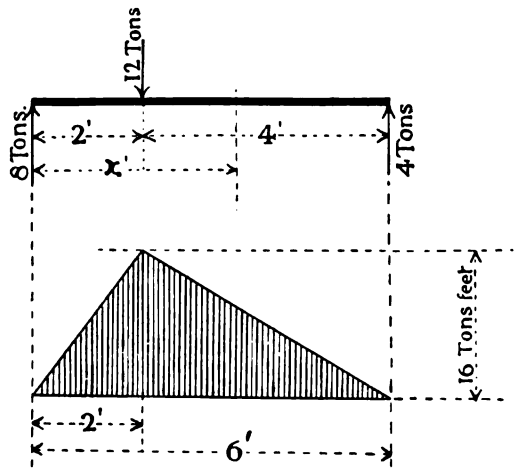

Fig 18. Pos. B.M. Diagram
[∴ plotted above base line.]

recognise the principle, even when it is stated in apparently diverse forms. The diligent reader will, however, quickly realise that there is no royal decree, and no established custom, determining what shall constitute a positive or a negative bending moment. Fortunately, however, the chief idea to be kept in mind is probably the simplest. It is, that the sign of the resultant does not affect its magnitude. Positive bending moments are frequently plotted above the base line of a diagram, and negative moments are plotted below. This is in keeping with the universal practice in co-ordinate geometry and trigonometry. This distinctive use of the upper and lower sides of a base line is made solely to prevent confusion, or to suit our convenience at the moment. When it is not convenient, we ignore the distinction between the upper and lower sides, and use both sides of our base line indiscriminately. Figs. 18 and 19 illustrate this principle.

To obtain the diagram given in Fig. 18, we must plot the values of the bending moment for several different values of x as under :—

Values of x . .	0	1	2	3	4	5	6
Values of B.M. .	0	8	16	12	8	4	0

We see at once that this will give us a triangle with a base representing the span to some convenient scale, and of a height which will represent the maximum bending moment to some other scale. We should notice also that the maximum bending moment occurs under the load. Therefore to draw the B.M. diagram for a single concentrated load on any part of a freely supported beam, we need only draw a triangle which fulfils the above conditions.

Before going deeper into the subject, it is, perhaps, desirable to draw the student's attention to the two distinct kinds of rules or laws which we have to deal with. In one class are the immutable laws of Nature and the truths of mathematics. These have been discovered and verified by man, but exist independently of him. An example of this class is the law that the measure of the tendency of a force to produce rotation in a body is jointly proportional to the magnitude of the force and the radius of action. The other class comprises arbitrary rules, or conventions, or "convenient customs." These have been made by man, and can be altered at our pleasure. An example of this class is our sometimes useful rule of plotting positive moments above a base line, and negative moments below that line.

In the former class of immutable laws must be placed the following proposition. The actual bending moment across any section of a beam, with several loads in any positions, is equal to the algebraic sum of the bending moment due to the separate loads. Let us take a simple, practical example which will illustrate this and several other of the principles already laid down. Fig. 20 (a) shews a beam having two unsymmetrical loads of different magnitude. The bending

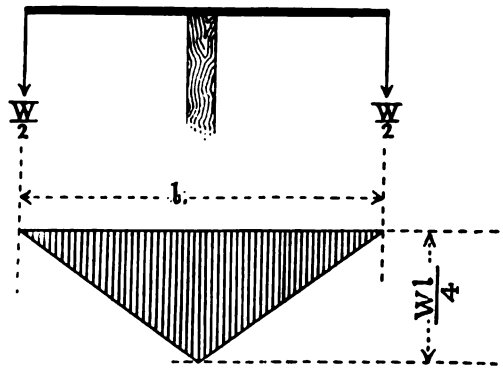

Fig 19
Neg. B.M. Diagram
[∴ plotted below base line]

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moment in ton-feet for any position of x between A and B $= 13{\cdot}5\,x$.

B.M. for any position of x between B and C

$$= 13{\cdot}5\,x - \{10\,(x-5)\}$$

B.M. for any position of x between C and D

$$26{\cdot}5\,(20-x).$$

The values of the B.M. are given for 21 positions of x in Table No. III. and have been plotted in Fig. 20 (b).

TABLE III.

Values of x	0	1	2	3	4	5	6
Values of B.M.	0	13·5	27·0	40·5	54·0	67·5	71·0
Values of x	7	8	9	10	11	12	13
Values of B.M.	74·5	78·0	81·5	85·0	88·5	92	95·5
Values of x	14	15	16	17	18	19	20
Values of B.M.	99	102·5	106	79·5	53·0	26·5	0

This example serves as an illustration of the principle that the actual bending moment across any section of a beam, with several loads in different positions, is equal to the algebraical sum of the bending moments due to the separate loads.

Let us work it out by this method. The left reaction caused by the imposition of the 10 tons load

$$= \frac{10 \times 15}{20} = 7{\cdot}5 \text{ tons.}$$

Maximum B.M. due to this load $= 7{\cdot}5$ tons $\times$ 5 feet $= 37{\cdot}5$ ton-feet.

The left reaction caused by the imposition of the 30 tons load

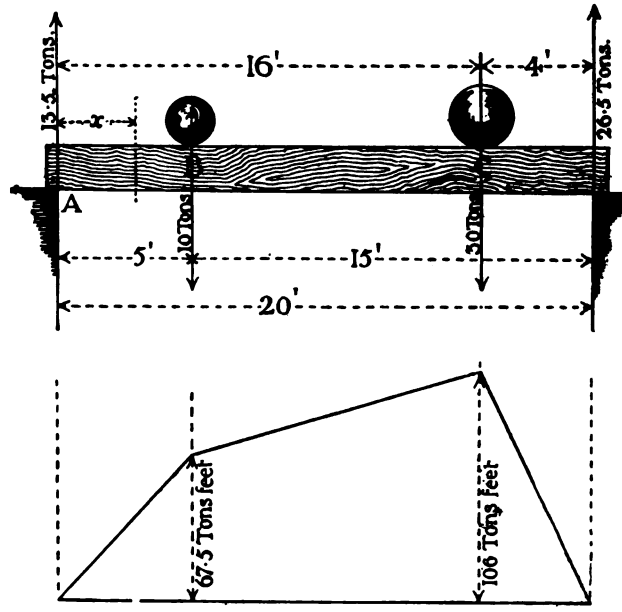
$$= \frac{30 \times 4}{20} = 6 \text{ tons.}$$

The maximum bending moment due to this load = 96 ton-feet.

From Fig. 18 we learnt a method of drawing the B.M. diagram for a concentrated load in any position. In Fig. 21 the diagrams for a 10-ton and a 30-ton load are both plotted on the same base line.

A B C A is the bending moment diagram for the 10-ton load, and A D C A is the B.M. diagram for the 30-ton load.

We want now to find some means of adding the ordinates of one diagram to the ordinates of the other. One method would be to separately take the ordinates in our compasses and add them together in a third diagram. We should then obtain a figure which would be an exact facsimile of Fig. 20 (*b*). There is, however, a simpler way. The bending moments were plotted above the base line because they both tended to make the beam concave on the upper side, and were therefore, positive moments. No confusion need arise if we abolish this self-imposed convention, so long as we remember that the moments themselves are of the same kind or sign, *i.e.*, positive. Let us, therefore, imagine the triangle A B C to be formed by a separate piece of paper hinged about the line A C. Let us then take the apex B of the triangle and revolve it through 180°, towards the reader, so that it lies flat down on the under side of the base line as indicated by the dotted lines A B_1 C. The total bending moment can then be found by measuring the vertical depth of the polygon A B_1 C D A. The sum of the bending moments added in this way will be found to



Figs 20a & 20b.

be exactly the same as given in Table No. III.

If the student will only take the trouble to try this for himself, any difficulties he may feel will disappear. Of course, in his subsequent work, the student would simply set one B.M. diagram on one side of the base line, and lay down the other diagram on the other

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side, and then measure vertically from one to the other.

The general solution is here given, but there is a particular case which is of some interest. It is the B.M. diagram for two equal loads equidistant from the centre of the beam. This latter case of equal equidistant loads is given in many of the text books, and the student who is anxious to deepen his knowledge and engrave the essential principles indelibly on his memory, should work out this and many other cases in detail, and by as many methods as possible.

Other important illustrations of this graphic addition of bending moments will be given during the course of these articles. The case next to be selected will be the bending moment diagram for a beam acted upon by its own weight, together with an independent load. This example will be worked out in detail, so that each step can be easily traced. First, it is obvious that every beam must be bent to a certain extent by its own weight. If we take a long shallow beam this deflection becomes appreciable. Now since every beam must bend under its own weight, it is self-evident that the fibres of the beam must undergo some alteration in length. Therefore, we see that this deflection of the beam is accompanied by internal stresses at every cross section of the beam. In fact, it is only a question of getting a beam long enough and shallow enough, and it will fail under its own weight. The fact is almost too obvious to be worth stating, but it is given here to induce the student to mentally reduce the length of the span and increase the depth of the beam, so that he may realise how the internal stresses are set up in a stiff beam. It should also be clear from the foregoing that our calculations of bending moment will be incomplete unless we include the bending moment due to the weight of the beam itself.

In practice we can usually obtain a very good idea of the probable external or extraneous loads which have to be carried, but we cannot fix the dimensions of the beam till we know its probable weight, and we cannot get its probable weight till we have fixed its dimensions. We are thus groping our way round a vicious circle. If we wish to avoid the laborious method of "trial and error," we must resort to some approximate and empirical formula for finding the probable weight of the beam. Such a formula is given below :—

Let W_g = probable total weight of girder in tons.

Let W = load on girder in tons.

Let L = span of girder in feet.

Let C = a constant depending chiefly on the type of girder, and the working stress allowed.

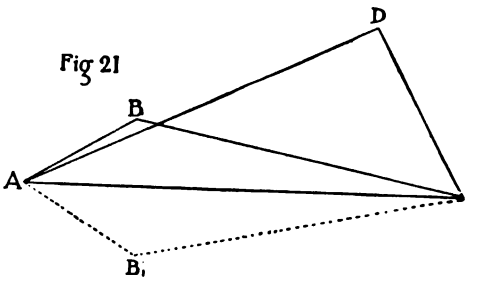
For a plate girder with uniformly distributed dead load, an average value of C = 500.

$$W_g = \frac{W\ L}{C} \quad \text{(Eqn. No. 8).}$$

$$\therefore C = \frac{W\ L}{W_g} \quad \text{(Eqn. No. 9).}$$

The student who intends to specialise in structural engineering might profitably take equation No. 9 and find the value of C for each girder he designs, and keep the figure for future reference. If the student does this, he will at least learn one thing. He will learn that this formula, though in common use, is only roughly approximate; and that the constant C is only constant in its inconstancy and variableness. A more exact, though lengthier formula, must be reserved for a later stage of our investigations. In the meantime the present rule may be taken as a safe one.

Fig 21



Let us take a numerical example as illustrative of the foregoing. Suppose we require a beam of 20-ft. span to carry a distributed load of 40 tons. By equation No. 7 our maximum bending moment due to the load on the beam

$$= \frac{W\ l}{8} = \frac{40 \times (20 \times 12)}{8} = 1200 \text{ ton-inches.}$$

The probable weight of the plate girder to carry this will be—

$$W_g = \frac{W\ L}{C} = \frac{40 \times 20}{500} = 1{\cdot}6 \text{ tons.}$$

The maximum bending moment due to the weight of the girder itself will be

$$\frac{W_g\ l}{8} = \frac{1{\cdot}6 \text{ tons} \times 240 \text{ inches}}{8}$$

$$= 48 \text{ ton-inches.}$$

In this case the B.M. due to the weight of the beam is small in comparison with the B.M. due to the load on the beam. In

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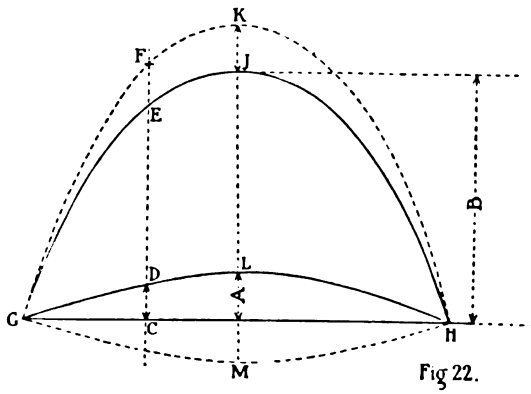

Fig 22.

cases where it is known that this occurs it is not unusual in practice to ignore the smaller and sometimes negligible quantity. Frequently some simple mental allowance is made for this extra B.M. in our calculations. However, we may have to deal with cases in which the B.M. due to the weight of the girder forms a considerable percentage of the true total maximum B.M. Let us try another numerical example. Suppose we have to carry a uniformly distributed load of twenty tons across a span of 100 feet.

$$\text{B.M. due to load} = \frac{W l}{8}$$

$$= \frac{20 \text{ tons} \times (100 \times 12) \text{ inches}}{8}$$

$$= 3{,}000 \text{ ton-inches.}$$

$$W_g = \frac{W L}{C} = \frac{20 \times 100}{500} = 4 \text{ tons.}$$

$$\text{B.M. due to weight of girder} = \frac{W_g \cdot l}{8} = \frac{4 \times (100 \times 12)}{8} = 600 \text{ ton-ins.}$$

In this case the B.M. due to the weight of the girder $= \frac{600}{3{,}600} = 16{\cdot}7\%$

of the total B.M., a quantity far from negligible. Since both these bending moments tend to make the beam concave on the upper side, they are positive moments, and as such, are plotted on the upper side of our base line. Let us plot them both on the same base line and add the ordinates afterwards (Fig. 22).

A = maximum B.M due to weight of girder. B = maximum B.M due to the super-imposed load.

There are at least four ways of summing these ordinates:

(1) By taking all such distances as C D in our compasses and setting them up as E F has been done, and drawing a curve through all the points thus given.

(2) By taking the distance A in our compasses and setting it up as K J and drawing a parabola through G K H. This method holds good because, if we add the ordinates of one parabola to the ordinates of another, the resultant curve is also a parabola.

(3) The third method is very similar to the last one. It is to add the weight of the girder to the load and find the resultant B. M. thus:

$$\text{max. B.M.} = \frac{(W + W_g) l}{8} = \frac{24 \times (100 \times 12)}{8}$$

$$= 3{,}600 \text{ ton-inches.}$$

Set up this 3,600 ton-inches as an ordinate on the centre of our base line and draw the parabola G K H in Fig. 22 without any reference to the two smaller parabolas.

(4) The fourth method is similar to the one adopted in Fig. 21.

It consists in discarding the exclusive use of one side of our base line, and imagining the parabola G L H to be turned through an angle of 180° towards the reader, round the axis, G H, and then measuring the depth of the resultant curvilinear figure; *i.e.*, the figure bounded by G M H J G.

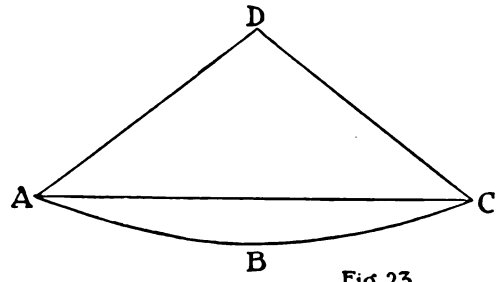

Fig 23

Let us briefly take up another important example of the combination of bending moment diagrams. Let us take the case of the central load of 20 tons on a beam of 60 ft. span. We can take the bending moments out in ton-feet and draw the diagrams, and afterwards alter our scale so as to read the bending moments in ton-inches direct. For instance, if the diagram be drawn to a scale in which one inch represents four ton-feet, we can convert this into ton-inches simply by reading off the bending moment to a scale in which one inch repre-

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sents (4 × 12) ton-inches. In the present example the B.M. in ton-feet

$$= \frac{WL}{4} = \frac{20 \times 60}{4} = 300 \text{ ton-inches.}$$

Now a comparison of Equations 6 and 8 shows that a central concentrated load of 20 tons produces the same bending moment, and therefore the same maximum transverse stresses, as a uniformly distributed load of twice this amount, assuming that the length of the beam is the same in both cases.

Therefore to obtain the probable weight of the beam we must insert the value of (2 × 20) tons in the Equation $\frac{WL}{500} = W_g$,

$$i.e., W_g = \frac{40 \times 60}{500} = 4{\cdot}8 \text{ tons,}$$

B. M. due to the weight of the girder = M tons-feet.

$$M = \frac{W_g L}{8} = \frac{4{\cdot}8 \times 60}{8} = 36.$$

These moments can be included in one diagram by the method previously employed (See Fig. 23). A B C A represents the B. M. diagram due to the weight of the girder. A C D A represents the B. M. due to the central load. A B C D A represents the diagram of total bending moments.

Concentrated Loads. In our previous work we have spoken freely and frequently of concentrated loads, and we have idealised our diagrams by showing our beams supported at the extremities on knife edges, or imaginary arrow-heads, etc. Let us now replace these impossible supports by brick-work and York stone, or other rational bearings, and see what alteration, if any, is required in our calculations. A concentrated load, like a point, is really a mathematical abstraction. A concentrated load or force has been defined as a load or force of finite magnitude, whose place of application is a point. Now a point has no mass, and a force cannot act on that which has no mass; therefore a force cannot act on a point. Again, the area of a point is zero, and if a finite force acts on zero area, the intensity of the pressure must be infinite. No matter how we look upon it, we cannot really conceive of a force acting at a point. Our loads of course really rest upon an area, and if the area is very large compared with the unloaded area, we call it a distributed load; if the area is comparatively very small, we call it a concentrated load. A concentrated load is therefore really a distributed load acting over a very small area. Now, in this area there must be some point at which the whole force may be *assumed* to act without affecting the reactions in any way. This point is called the *centre of pressure.* With a perfectly-formed homogeneous cube resting upon a perfectly level surface, the centre of pressure passes through the centre of the cube.

It is usual to design built-up girders with about 1 inch initial camber or rise for every 40 ft. of span, so that when the girder is loaded it will not sag. If the girder has also been designed so as to deflect about 1 in. for every 40 ft. of span, we may safely assume that the loaded girder will lie in a practically straight horizontal line, and that the pressure on the bearing plates will be uniform. When the pressure is uniform, the centre of pressure of the upward reactions will pass through the centre of the bearing plate area.

Let us determine the exact bending moment for a beam with real and not ideal supports, as shown in Fig. 24.

Let W = total weight of girder + total load.

w = combined weight per foot run.

$W = w.t.$

Take moments round the centre for the external forces on the left half of the beam, then B.M.

$$= \frac{W}{2} \cdot \frac{l}{2} - \frac{W}{2} \cdot \frac{t}{4}$$

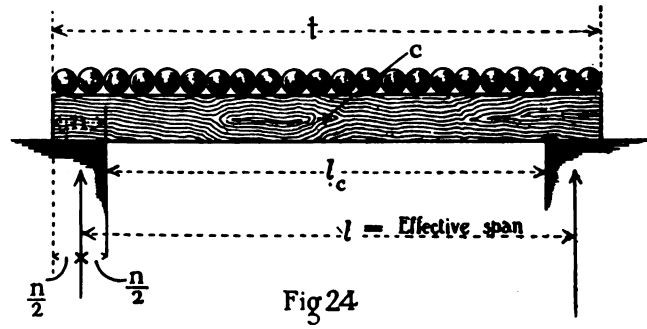

Fig 24

$$= \frac{W \cdot l}{4} - \frac{W \cdot t}{8}$$

$$= \frac{2}{8} W \cdot l - \frac{1}{8} W \cdot l$$

$$= \frac{2}{8} W \cdot l - \frac{1}{8} W (l + n)$$

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$$= \frac{2}{8} W l - \frac{1}{8} W l - \frac{1}{8} W n$$

$$= \frac{W l}{8} - \frac{W}{8} n \text{ . [Eqn. No. 10.]}$$

Let l_c = 25 feet; l = 26 feet; l = 27 feet; n = 1 foot; and w = one ton per foot run.

Then by Eqn. No. 10

$$\text{B.M.} = \frac{27 \text{ tons} \times 26 \text{ feet}}{8} - \frac{27 \text{ tons} \times 1 \text{ foot.}}{8}$$

$$= 84{\cdot}375 \text{ ton-feet.}$$

Let us now try several approximate methods to see if we can obtain a shorter method of finding the B.M. within limits close enough for purposes of practical design. Let us, for a trial, assume that the reactions are at a distance apart equal to the clear span, and that the beam is only loaded between these limits. The load in this case will be 25 tons, and the maximum B.M. will be

$$\frac{W l_c}{8} = \frac{25 \times 25}{8} = 78{\cdot}125 \text{ ton-feet.}$$

Let us now try, with the reactions at their true positions, and with the beam loaded only between these points; in this case the B.M. will be

$$\frac{W l}{8} = \frac{26 \times 26}{8} = 84{\cdot}5 \text{ ton-feet.}$$

Let us now assume a beam 27 feet long, with the reactions occurring at the very extremity of the beam. The load will be 27 tons, and the B.M. will be

$$\frac{27 \times 27}{8} = 91{\cdot}125 \text{ ton-feet.}$$

It will be seen that when we take the bending moment on an idealised or theoretical beam, of length equal to the effective span of the real beam, we get a maximum bending moment which is about 0·15% greater than the true bending moment for this particular case, and this is quite close enough for all practical purposes; a trial with other spans and practical bearings will show that this method comes nearer to the true B.M. than the other two alternatives tentatively adopted. *We see, therefore, that in calculating the bending moment for built-up cambered girders, loaded from end to end, we should put the length of the effective span in our* $\frac{W l}{8}$ *formula.*

There are still two other important variations in end conditions which affect the position of the centre of pressure of the reactions. These points are being dealt with in detail, so as to bring home to students the assumptions which are made when we apply our theories and arithmetical approximations to the practical problems of design.

(To be continued).

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PLANNING, SETTING-OUT, AND MAKING STAIRCASES.

PART I.

By HENRY JARVIS.

THERE is probably no branch of the carpentry and joinery trades which is so much neglected, both in the shops and in technical schools, as that connected with the planning and setting-out of staircases. Perhaps it would be more correct to say *passed over*, instead of *neglected*, as during years of observation I have noticed that the efforts made to teach apprentices and students even the rudiments of the stair-builder's art are very slight indeed; and, in many cases, when there has been an inclination on the part of a youth to gain information in this branch, he has been discouraged in every way. As a consequence, it is a rare occurrence to find a carpenter and joiner who is capable of building an ordinary staircase, unless it is set out for him and a strict supervision is exercised over his work.

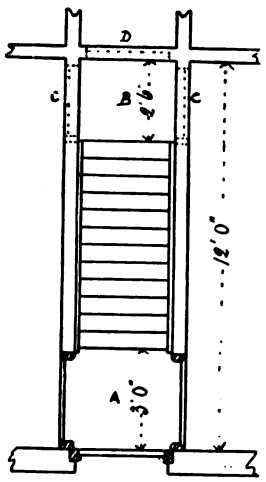

FIG. 1.—PLAN OF STRAIGHT STAIRCASE.

We all know the idea of this conservatism—to keep staircasing as a distinct branch, in the hands of a select few. But why this should be so it is difficult to say; and the writer having had the misfortune, many years ago, to feel the evil effects of the system, he has, since overcoming his own difficulties, endeavoured to impart information to those in the same plight. It is to be hoped that this short series of articles may be the means of clearing away some of the stumbling-blocks, and making it more easy travelling for students desirous of advancing themselves in the future.

It will be well to mention at once, that in planning stairs, it will not do to push them into any corner; since it is necessary to have a certain amount of space horizontally, in proportion to the height, or it is impossible to get even a passable staircase. The neglect (or, I fear, in many cases, the ignorance) of this necessity, is the cause of so many steep, awkward staircases being erected, even in good houses.

Again, in measuring for, and setting out stairs, there must be no "near enough." The measurements must be exact. For instance, if the height of each step happens to be a fraction over seven inches, this fraction must be taken into account in making the step board, or the treads will not be level in the finished stairs, unless the bottom and top steps are made higher than the others, as is often the case; but as two wrongs never make a right, so in the stairs the remedy only makes matters worse.

We shall now consider a few actual examples in the abstract, to be followed, later on, by instructions in setting out and building.

In Fig. 1 we have a very familiar case. The front door is in the centre of the front of the house, with a room at each side, the

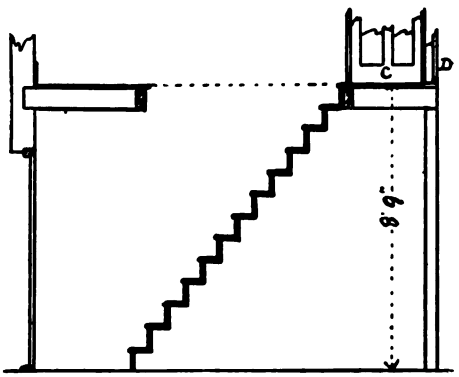

FIG. 2.—SECTIONAL ELEVATION OF FIG. 1.

stairs going up between the two rooms. Now we have only 12 feet from the front wall to the division wall, and out of this we require 3 feet at the bottom of the stair, A, and at least 2½ feet at the top, B, where doors

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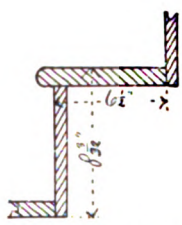

FIG. 3.—ENLARGED DETAIL OF ONE STEP (FIG. 1).

branch off at each side, C, into the front bedrooms, and the door at D into the back part of the house. Thus we have 6½ feet left for the stairs, or, in technical terms, the "going."

We shall now consider the height of the staircase. The rooms cannot be less than 8 feet pitch, which, with 8-in. joists and 1-inch flooring, will bring us up to 8 feet 9 inches from the bottom to the top of the stairs. This height, therefore, must be divided equally into suitable "rises" to form the stairs.

In Fig. 2, which gives a sectional elevation of the stairs shown in plan in Fig. 1, we have thirteen rises, so that each works out at about $8\frac{3}{32}$ inches, and is as high as can conveniently be used.

The "going" of 6½ feet must be divided in the same way, but into twelve parts only (the reason for which will appear later on), and this will give us a "going" for each step of 6½ inches, which, with the additional inch in width for the nosing, will make a tread of 7½ inches, as shown in detail in Fig. 3.

The above would not, in many parts, be called a steep staircase, but it certainly cannot be called an easy one; and in Fig. 4 is shown in sectional elevation, how to make it decidedly easier, with very little extra work.

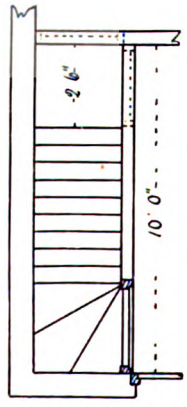

FIG. 6.—PLAN OF STAIRS WITH THREE "WINDERS" AT BOTTOM.

Instead of taking the stairs up to the landing E, as in Fig. 2, the joists are cut away entirely, and a false landing put in, eight inches lower down, as at F; thus giving a step up into each room from the landing, and making the height of the stairs 8 feet 1 inch only. This height, divided into the thirteen "rises," will give barely 7½ inches per rise, instead of the full eight inches as before, thus forming a comparatively easy staircase in place of a steep one. Fig. 5 shows the enlarged detailed section of the step in Fig. 4, and the difference can at once be seen by comparing Figs. 2 and 3 with Figs. 4 and 5.

Fig. 6 illustrates a state of affairs which is of common occurrence; the front door opens into the room direct, and is placed far enough from the corner of the house to allow the stairs to be placed in the recess thus formed. The room is also very narrow, only 10 feet from the front to the division wall, which is of necessity reduced to 7½ feet by the landing at the top of the stairs. It is therefore out of the question to deduct a further 2½ feet at the foot of the stairs, as this would make the tread so narrow and the rises so high, that it would almost be an acrobatic feat to ascend to the bedrooms.

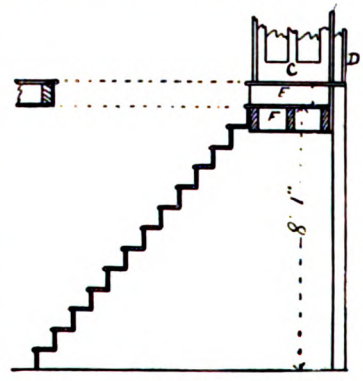

FIG. 4.—SECTIONAL ELEVATION OF STAIRS, WITH FALSE LANDING.

In these circumstances we have no alternative but to resort to a winding staircase, which, although very necessary in such cases as the present, should be avoided whenever possible.

A glance at the sectional elevation in Fig. 7 will show that by the aid of the three winders at the bottom, instead of a level landing, we are carried up four steps without any loss of going whatever. Thus by dividing the full height of 8 feet 9 inches into thirteen "rises" of a trifle over 8 inches each, as in Fig. 1, we attain the height of 2 feet $8\frac{3}{8}$ inches, and have the whole 5 feet of going to divide between the remaining nine treads, which gives us a going of barely 6¾ inches, making, with the nosing, a

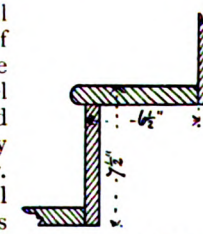

FIG. 5.—ENLARGED DETAIL OF ONE STEP (FIG. 4.)

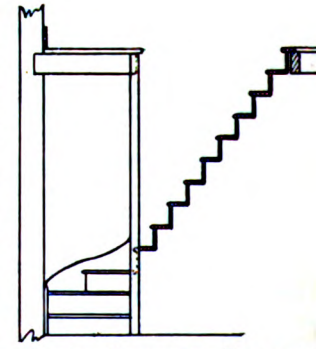

FIG. 7.—SECTIONAL ELEVATION OF FIG. 6.

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tread of nearly 8 inches wide, or almost identical with Fig. 4.

The above stairs can be made still more easy by inserting a false landing, as in Fig. 4; but this is hardly necessary unless for very special reasons.

The plan in Fig. 8 and sectional elevation in Fig. 9 illustrate a very good form of staircase, suitable for a better-class house, where it is possible to obtain a hall space of 6 feet in width. It consists actually of two flights of stairs, the bottom flight ending at the half-space landing, which also forms the starting-point for the top flight. It is thus possible to obtain a very easy staircase indeed.

The drawings show what is called a "dog-leg" staircase, with bull-nose step at the bottom. The right-hand string of each flight is tenoned into the newel G, the latter extending down to the floor, where it serves as the door-post as shown, thus forming a very convenient way of getting from the hall to the kitchen.

More elaborate stairs of this character are the "square well," in which a separate newel is used for each string, the two being connected by a short string board; and the "continuous string," in which the newels are dispensed with entirely, the string being bent round in one continuous line. Both of these, and some others will be illustrated and described later on.

In the next article it will be shown how to measure for, set out, make, and fix an ordinary straight staircase to a definite plan, which can be utilised by making a scale model of the same, say quarter full size; if this is done throughout the series, the student will not only be possessed of a useful and interesting set of models, but will also have gained such experience that he will be able to undertake the construction of a real staircase when opportunity arises.

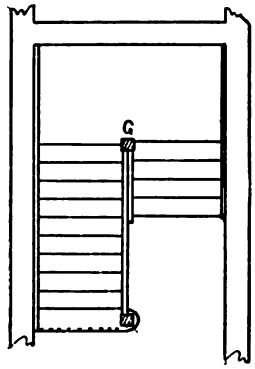

FIG. 8.—PLAN OF "DOG-LEG" STAIRCASE.

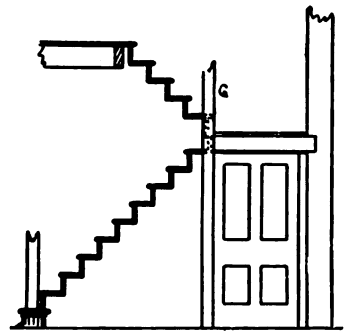

FIG. 9.—SECTIONAL ELEVATION OF FIG. 8.

(To be continued.)

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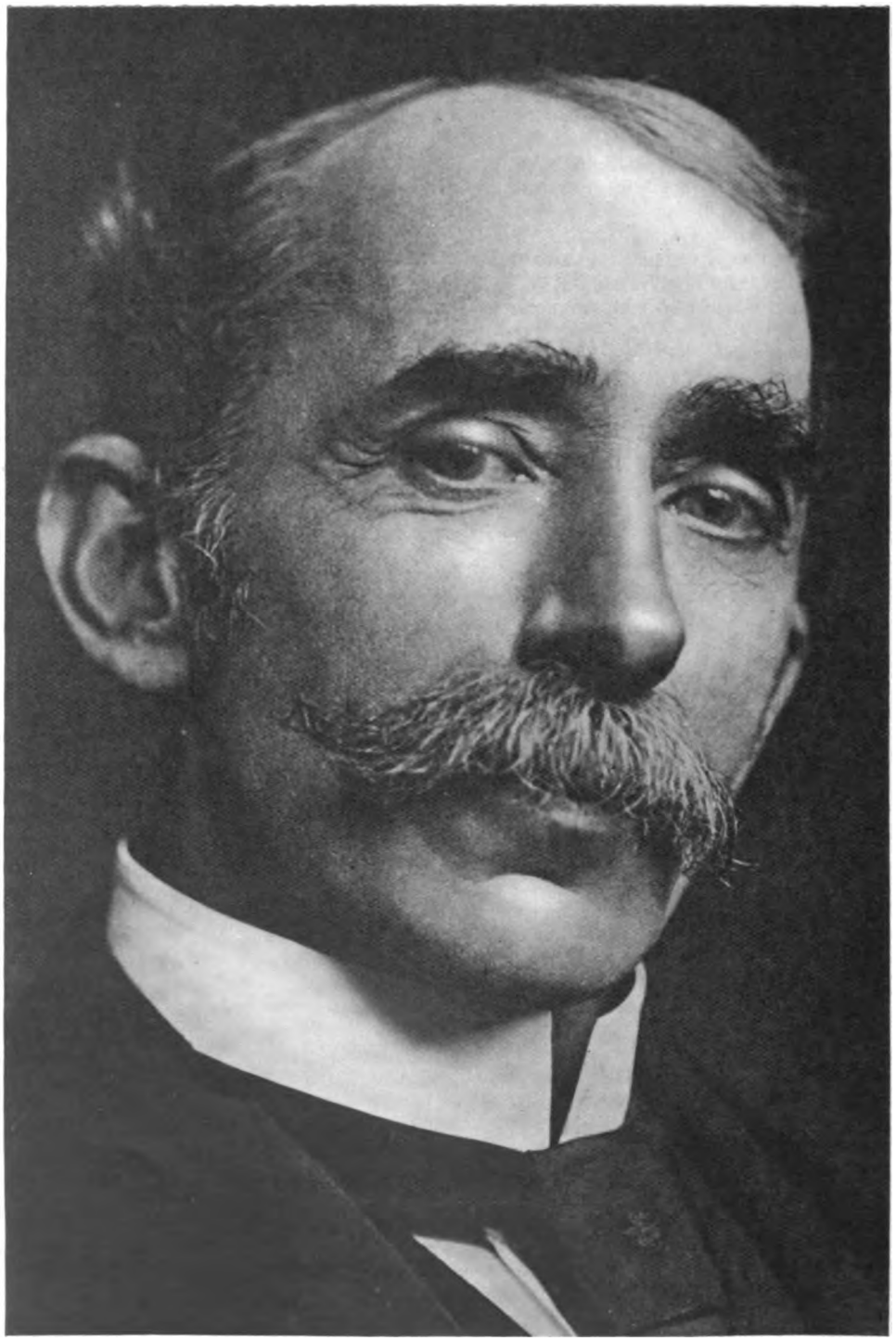

Dr. J. A. FLEMING, F.R.S.

Photo by George Newnes, Ltd.

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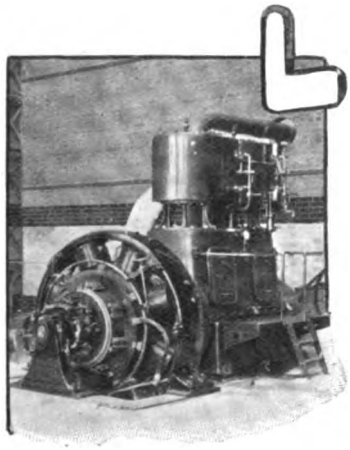
ON THE EDUCATION OF ELECTRICAL ENGINEERS IN LONDON.

By Dr. J. A. FLEMING, F.R.S., Professor of Electrical Engineering in University College, London, Vice-President of the Institution of Electrical Engineers.



LONDON, the metropolis of the British Empire, is a great centre of electrical engineering. In and around London there are many large electric supply stations, such as those at Bankside, Deptford, Willesden, Westminster, and those of the Borough Councils of St. Pancras, Hampstead, Hammersmith, Shoreditch, and Islington.

There are also great power stations in operation, and in process of being completed, for present and new tube railways, such as the Central London Railway power station at Shepherd's Bush, the Great Northern & City Electric Railway power station, and the immense electric power stations being built at Chelsea and Neasden for the electrification of the Metropolitan District and the Metropolitan Railways.

Electrical Industries near London

There are also important electrical factories in the neighbourhood of London, viz., the Edison Swan electric lamp factory; Messrs. Siemens Bros., of Woolwich; the Telegraph Construction & Maintenance Co.; Messrs. Henley & Co.; and Messrs. Johnson & Philips.

Whilst we are somewhat behindhand in electric traction, compared with provincial towns, there is, nevertheless, indication that this leeway will soon be made up, and that in addition to the large systems of electric traction provided by the London United Tramways Company, the London County Council South London conduit systems will be rapidly extended.

Large as is the present development of electric enterprise in London, it is, however, nothing compared with that which will be witnessed in a few years, when our main line railways commence in earnest the work of electrification of their suburban lines, and when all proposed tube and tramway systems are complete. Hence the provision for the training of young men to assist in this work is an important matter.

Earliest Educational Schemes

Until about twenty-six years ago, with the exception of certain schools of telegraphy, hardly any organised arrangements existed for the training of men in electrical technology. In fact, at that date, telegraphy and telephony and electroplating comprised nearly the whole of the technical applications of electricity. In 1877, the subject of technical education began to attract general attention, and in 1878 resulted in the formation of the City and Guilds of London Technical Institute.

In 1882 the commencement of practical electric lighting gave a great impulse to electrical engineering, and the need was felt for more systematic means of training men to supply the demand for competent assistants and workers able to develop the new industry.

In 1883 the Technical College at Finsbury was opened by the City and Guilds of London Technical Institute, and subsequently the Central Technical Institution was also founded by them in the Exhibition Road, South Kensington.

In 1885 the Council of University College determined to establish a chair of electrical engineering, and invited the writer of the present article to fill it.

In 1892 a department of electrical engineering was created at King's College, by the aid of an endowment made to commemorate Sir William Siemens, and was placed under the control of the late Dr. John Hopkinson.

About the same date many of the present Borough Councils began to take an interest in technical education, and the Technical Education Board of the London County Council was brought into existence.

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By the aid of public subscriptions and the appropriation of public money, polytechnics and technical institutions were built and equipped in many districts of Greater London, and in nearly all of these, departments and laboratories for training students in the scientific principles of engineering and electrical engineering exist. The following list of Institutions comprises those which have established such engineering departments: the Goldsmiths' Company's Technical Institute, New Cross; the South Western Polytechnic, Manresa Road, Chelsea; the Polytechnic, Battersea; the Polytechnic, Regent Street; the Borough Polytechnic Institute, Borough Road; the London County Council Paddington Technical Institute; the Polytechnic, Woolwich; the Northampton Institute, Clerkenwell; the Hackney Technical Institute, Hackney Downs; the Northern Polytechnic Institute, Holloway; the West Ham Technical Institute; East London Technical College, Mile End Road.

Polytechnics

In addition to these public institutions there are some private schools, of which the principal one is the Faraday House Electrical Training and Standardising Institution in Charing Cross Road.

Accordingly we have in London and Greater London some sixteen or seventeen colleges and institutions, in which provision is made for the training of electrical engineers, and in view of the proposals that have been recently made for the establishment of some institution of a still higher rank, more especially to be devoted to advanced teaching and research, it will no doubt be interesting to the readers of "Technics" to be furnished with a short account of the provision which is at present made in London for the training of electrical engineers; whilst at the same time the deficiencies of the present arrangements are pointed out, and some suggestions made as to the lines on which future development should take place.

Number of Electro-Technical Institutions in London

Beginning with the oldest college in which this work commenced, viz., the Finsbury Technical College in Leonard Street, we find from the records that this college was in active operation in 1884, with over one hundred students training in electrical and mechanical engineering.

Under the present Principal, Professor S. P. Thompson, F.R.S., a teacher of world-wide reputation, the teaching has been organised on such lines as to maintain complete touch with the development of electrical engineering, and, in fact, in many respects to guide it. The instruction is given, as usual at most colleges, partly by lectures, but mainly through the laboratory work done by the students themselves. The students in the laboratory work in groups of two or three, at carefully arranged progressive exercises or tests, training them to become careful observers and to record in reports and curves the results of observation, whilst they acquire real knowledge by experimenting with real machines. One feature of the college is the possession of an electroplating and electrotyping laboratory in which much useful teaching has been done.

Finsbury Technical College

The advanced students take part in original research, assisting, or under the guidance of, the Professor; and numerous original communications and memoirs proceed every year from the college, over and above those standard treatises from the accomplished pen of the Principal, which are classics in electrical literature.

The college is open day and evening, and in the last session there were 109 day and 256 evening students in the department of electrical engineering. Since the beginning, 2067 day students have passed through the college, and a glance at the college calendar, showing the important positions now filled by many old Finsbury students, is the strongest proof of the highly practical and thorough character of the teaching given. It is noteworthy that it is many years since any Finsbury student, who has successfully completed his course, has had to pay a premium to enter upon his electrical career in life. Day students are required before admission to pass an examination in mathematics and English, and at the end of the first year's course are not admitted to the advanced course unless they give evidence of profiting by the instruction. The fee for day students for a complete course is £15 for the session. Certificates and scholarships are awarded on the results of the college examinations.

As already mentioned, the chair of electrical engineering at University College was created in 1885, and the present writer was invited to fill it. At that time no laboratory appliances or accommodation existed for the proper teaching of electrical engineering in University College, but one or two rooms were set apart for this purpose, and a small amount of apparatus provided. In spite, however, of

University College, London

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the limited nature of the appliances, a course of lectures was established dealing with the principal applications of electrical science in engineering, and a small amount of laboratory work was conducted. This state of affairs continued for eight years, during which time 170 students passed through the department.

In 1892 the Council of University College were brought face to face with the necessity for erecting new laboratories for the department of mechanical and electrical engineering, and accordingly the present engineering wing of the college was built and equipped at a cost of £20,000. The laboratories were opened by H.R.H. the Duke of Connaught in May, 1893.

In this new wing one half of the building was devoted to mechanical engineering and the remainder to electrical engineering. The electrical engineering department comprises a lecture room, capable of seating about sixty students, a working laboratory, an apparatus room, a dynamo room, an accumulator room, and a small workshop.

For the equipment of this department with apparatus, the Council provided about £800. £800 more were collected by the present writer from personal friends and friends of the college. At a somewhat later date, after the death of Sir John Pender, his friends and business associates determined to create a memorial, which finally took the form of a presentation to University College of a sum of £5,000, the interest of which has since been devoted to the extension of the electrical plant. The laboratory was then christened the Pender Electrical Laboratory. This fund, together with certain other grants from the Technical Education Board, has enabled apparatus to the value of about £3,000 to be accumulated. From time to time, also, gifts of apparatus have been received from manufacturing firms.

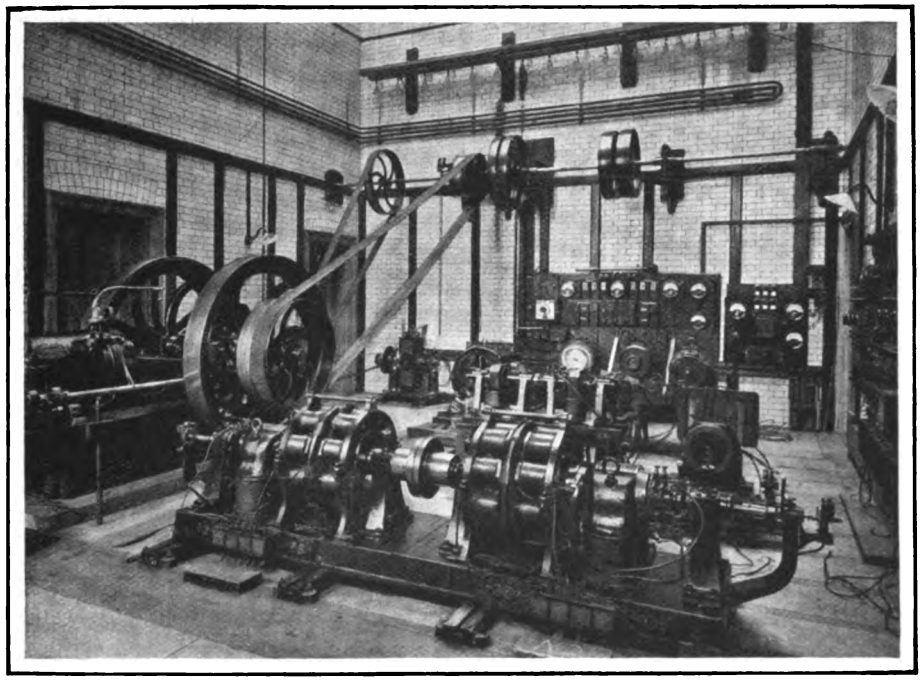

Photo by *George Newnes, Ltd.*

THE DYNAMO ROOM, PENDER ELECTRICAL LABORATORY, UNIVERSITY COLLEGE.

The space at disposal not being very large, the engines, dynamos, transformers, and most of the working machinery, are small, but owing to the care in which the selection has been made they are of modern type, and all appliances, so far as they go, are very complete. The laboratory is well stocked with measuring instruments of all kinds, and the arrangements of the photometric gallery for the photometry of arc and incandescent lamps are particularly complete, and photometric measurements have been made a speciality in the Pender Laboratory.

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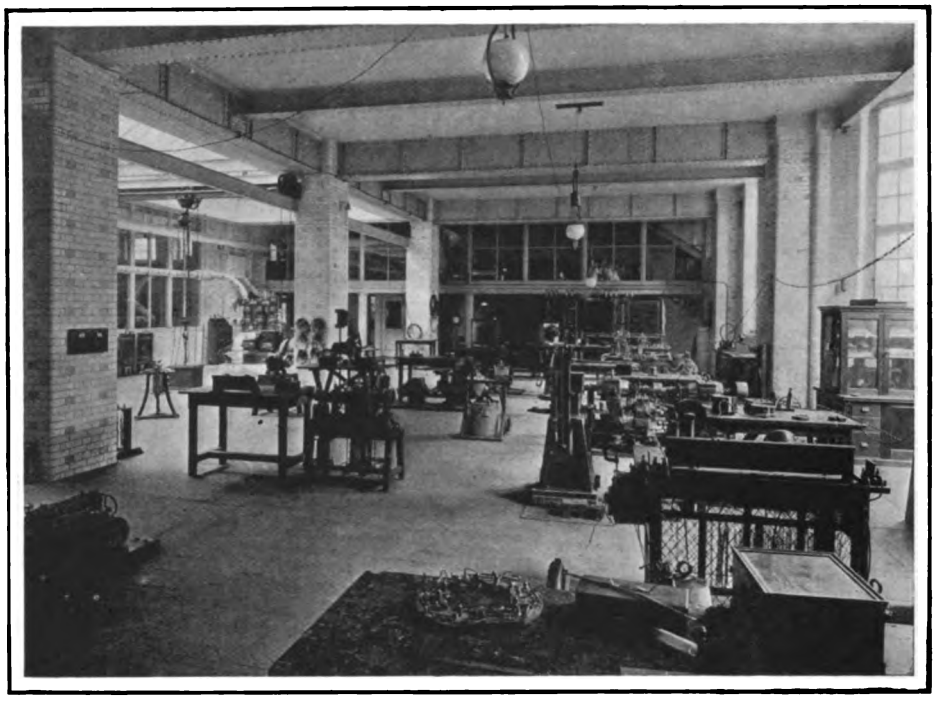

Photo by DYNAMO ROOM, CENTRAL TECHNICAL COLLEGE. *George Newnes, Ltd.*

The course of instruction given in these laboratories is partly by lectures and class work, but principally by individual work done by the students in the laboratory. The majority of the students take up a complete engineering course extending over two or three years, but a large number of men who have already been engaged in practical work come for a shorter time to complete their theoretical training. Each student, as far as his time and diligence permits, is taken through a course of practical work; the object of this is to train him to use all the ordinary electrical instruments, and to make all the necessary tests of dynamos, motors, transformers, lamps, and so on, which are required in an electrical factory, as well as to make him a careful and accurate observer and intelligent investigator, and train him in the art of questioning nature. The advanced students take part in pieces of original research, or are set to special investigations. A crying want, however, is additional laboratory space for this purpose.

Individual Work of Students

Research Work

There are generally about forty students working in the electrical laboratory, and in the past eleven years, between five and six hundred students have passed through the department, many of whom having since made their mark in the world.

Three times in the last ten years the 1851 Exhibition Commissioners have awarded one of their valuable scholarships of £150 a year to a student in the Electrical Department of University College, to enable him to spend time in original research; and several such exhibition students have come from other colleges to work in the Pender Laboratory. Likewise many foreign students have gone through a course of training in it; coming from Sweden, Germany, France, Italy, and Japan. One Chinese student went through the electrical course, and returned last year to carry with him the fruits of his study to the Flowery Land. Many of the senior students have aided the writer in original investigations, and some sixty original papers have been published by him in the last fifteen years, in which valuable aid or co-operation has been received from students and assistants. Owing to the small teaching staff, the teaching work has to be carefully organised.

Students

In the last nine years evening classes have also been conducted in connection with the Technical Education Board of the London

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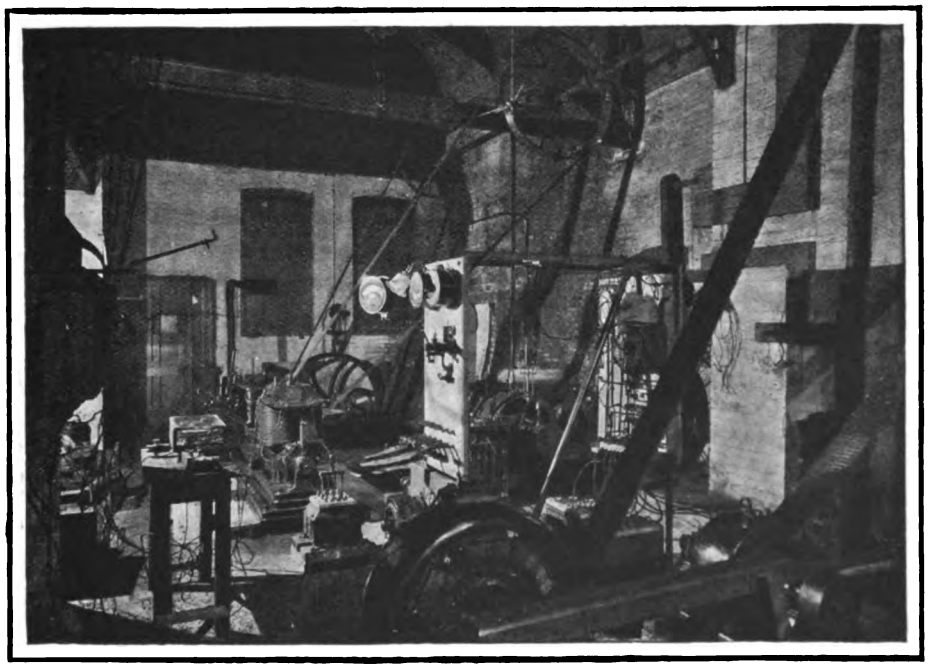
County Council. This board makes a grant to University College of £1,500 per annum; and as a *quid pro quo* fifty free students, selected by the board from schools and institutes under their control, are taken by the college.

The fees for a diploma course of three years amount to about £35 or £40 a session, but students are accepted for any of the courses without examination, provided they give evidence of being able to profit by the teaching. Within the last year or two an influential Committee has been formed, of which Sir Alexander Binnie is Chairman and Mr. Leslie S. Robertson Hon. Secretary, to obtain assistance, in the form of donations and apparatus for the Engineering Laboratories of University College.

The Central Technical College

In the next place, we have the Central Technical Institution in Exhibition Road, South Kensington, forming the principal college in London at which electrical engineering is taught. This college was founded by the City and Guilds Institute to practically demonstrate and teach the application of different branches of science to various manufacturing industries. Like the Finsbury College, its work is concerned chiefly with mechanical and electrical engineering and chemistry. Students are admitted after passing an entrance examination, and go through a complete or diploma course, the fees for which are £30 a session for matriculated students, and £35 for others. The work in this college is done in the daytime. The electrical department is under the charge of Professor W. E. Ayrton, F.R.S., whose great experience and fame as a teacher and man of science have contributed largely to the reputation of the college.

From first to last, the City and Guilds of London have expended on this college about £200,000. Recent additions have been made to the laboratory accommodation, and it stands to-day as one of the most finely-equipped technical schools in the country. Yet, nevertheless, it is the teachers, and not the mere plant which make a college. A laboratory may be stocked with every conceivable piece of apparatus which money can buy, and yet be absolutely sterile as regards contributions to original knowledge. At the Central Institution, however, the teachers are makers of new knowledge, as well as teachers of that which is known, and in the last seventeen or eighteen years a continual stream of valuable scientific



DYNAMO ROOM, KING'S COLLEGE.
(From a Photo.)

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investigations has emanated from the institution. But, more, they have not only made knowledge—they have made men. The highest test of a college is the men it produces. Does it turn out mere examinees, book students, retailers of other men's ideas; or does it send forth men with initiative, invention, power of grappling with new problems, and applying principles to practice?

Results of Training

We can glance down the lists of old students of the Central Institution and find the names of men who are now in high positions, and who have since made their mark as scientific investigators and inventors.

The principal aim of the college is therefore to bring students as quickly as possible to the point at which they can take part in original research, and the chief work of the professor is that of guiding and organising the work of this character which is being done.

King's College

At King's College, the electrical laboratory was founded to commemorate Sir W. Siemens, and is accordingly called the "William Siemens" Laboratory. The late Dr. John Hopkinson, F.R.S., was elected to fill the chair of electrical engineering at King's College on its creation, and after his lamented death was succeeded by Professor Ernest Willson, M.I.E.E., formerly assistant to Dr. Hopkinson. The laboratory has been well equipped with modern electrical machinery and electrical apparatus for carrying out all the necessary tests, and for training students in the processes of electrical measurement. The latest additions to the plant comprise a complete traction equipment, consisting of motors, under-truck, controllers, etc., all arranged for testing; also a polyphase 20 kilowatt generator, rotary converter, induction motors and regulating apparatus. Courses of instruction are arranged for the day and evening. There is a regular four years day course in mechanical and electrical engineering, the winter sessions being passed in the college and the summer sessions in engineering works.

The "Sandwich System"

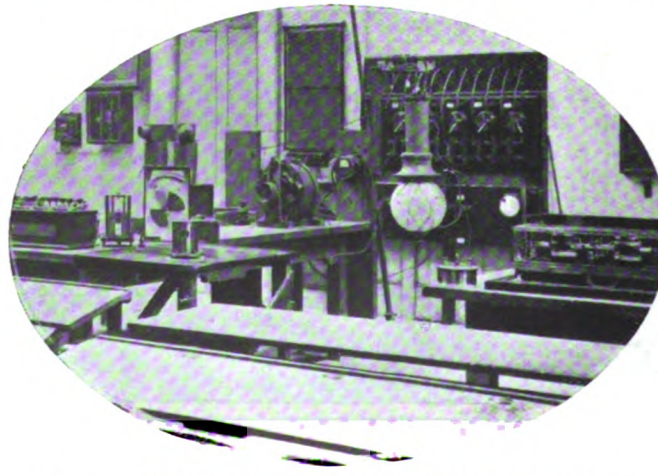
This course is thus a "sandwich system," the student conducting his works apprenticeship intermingled with the college course. There is also complete a three years entire college course, and a special course in electrical engineering for non-matriculated students. The matriculated students pay a fee of fifty guineas per annum, but non-matriculated students, attending the electrical engineering course daily, pay a fee of £21 per annum.

The lecture and laboratory courses are arranged so as to give the students a complete training in the scientific principles underlying electrical engineering, and also a thoroughly practical knowledge of the use and working of electrical machinery. A large amount of valuable research work has been carried out by the Professor and his assistants during the years the laboratory has been established.

There are also evening classes at King's College in electrical engineering, and the total number of day and evening students in the faculty of engineering, at present, is as follows: –

Matriculated, 115 day students; and non-matriculated, 114 day and 291 evening students.

(*To be continued.*)



ELECTRICAL ENGINEERING LECTURE ROOM, KING'S COLLEGE.

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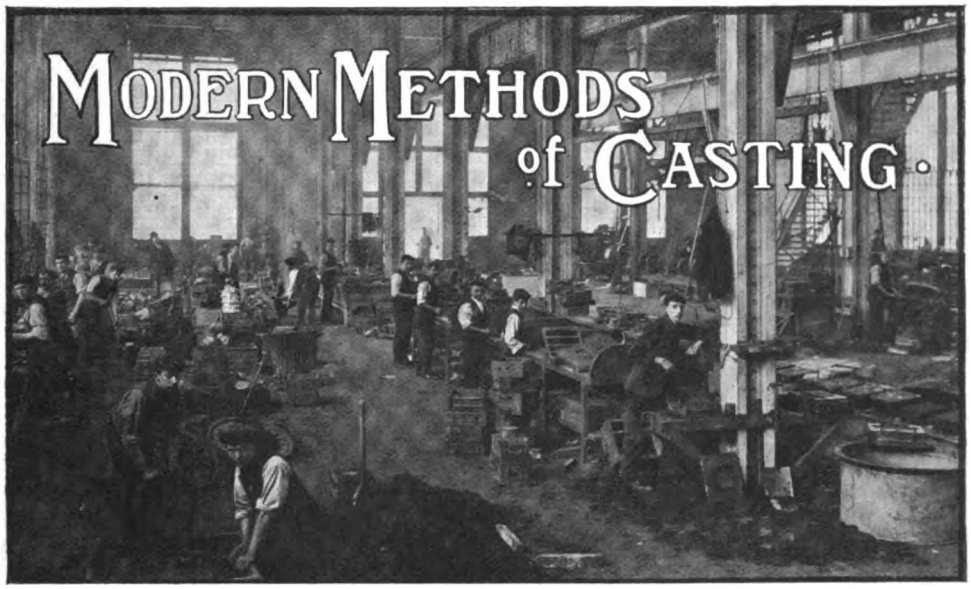
Modern Methods of Casting.



Brass Foundry, British Westinghouse Company.

By JOSEPH G. HORNER, A.M.I.Mech.E.

FOUNDRY methods certainly date back to 2,000 or 3,000 years ago, for neolithic man has left rich stores of bronze castings in Swiss lakes and in tombs; ancient hoards comprising celts, chisels, gouges, pins, articles for attack and defence, for domestic use and ornament, which testify to a very high degree of skill in moulding and casting. Some sand moulds have survived, along with those of stone, with cores *in situ;* together with metal chills, both for open and closed moulds; dowell pins, ingates or runners, and runner heads or "gits," with all of which the neolithic moulder was as familiar as his successor of to-day. Truly, founding is one of the most ancient of crafts.

In explaining the modern methods of the craft we must admit that the underlying physical principles are unchanged. No novel principle can be, or has been discovered, since natural laws control the behaviour of metals when poured into moulds and during cooling; the properties of the different materials of which moulds are made, and so forth, are also subject to unchangeable laws. The methods of the present day differ from those of past generations chiefly in the growth of labour-saving devices: in various provisions having for their object greater precision and uniformity of results in the production of numbers of castings; and in a more exact grading of metals and alloys, with a view to securing the best results that can be obtained in this direction. Since each one of these aspects of the subject admits of very extended treatment, I propose to dwell more fully on some than on others—those, namely, which come under the head of labour-saving devices.

Students and young engineers, whose acquaintance with the practice of foundries is not extensive, can hardly be expected to grasp the significance of the changes which are proceeding on the lines just indicated. Each year old-fashioned methods become more strongly contrasted with modern procedure. A generation since—even a dozen years ago—there were no very great differences between foundries, save those necessarily due to variation in the size and class of the work handled. Apart from these differences, foundries were everywhere pretty much alike with regard to their methods of carrying the work through. At present this is no longer the case; we have foundries of the most advanced types; others remain unchanged and unchanging; while a large number—perhaps the largest proportion—are more or less in a state of transition. Things are moving very rapidly, and those

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who will not change must be left behind in the international struggle for industrial supremacy.

The following is a picture of the ordinary old-fashioned foundry :—

Every mould, small and large alike, is produced by the skilled hand-labour of the craftsman. If light, it is poured by hand, the metal being carried from the cupola in hand-ladles. If heavy, it is poured from a ladle slung in a crane of the swinging jib type, usually operated by hand. The castings are knocked out, and fettled or cleaned by hand, using cold chisels and files. Metal is graded by the appearance of fractured surfaces only: it is melted in cupolas with coke that has not been subjected to analysis, and which is frequently not weighed out in suitable proportions to the metal. The buildings are almost always dark; many, in fact, require artificial light on dull days. There is no adequate storage, no proper system of handling materials and work, so as to secure economy of time and labour. The production of the various moulds and castings is not subdivided and apportioned so much as it might be. The men are mostly general hands; skilled men frequently give a turn at unskilled labourers' tasks. Such, in briefest outline, is a picture of the average old-fashioned foundry, of which many hundreds exist to-day. They still make money easily, so good is the margin of profit; but year by year they are becoming more hardly pressed by the modernised firms.

We are now in a position to understand some of the principal differences between the old and newer foundry practice.

"Labour-saving devices" is a phrase of most comprehensive and general character, including a vast number of items, which vary widely in different foundries, since the numerous classes of work done impose conditions which permit of no fixed rules. Thus, no explanation is necessary to show that in a foundry where heavy marine or hydraulic work is the staple product, the conditions are totally different from those which exist in one doing standard cock and valve work, or small stationary engine work, or small pumps, or malleable iron, or brass castings. In the former, skilled hand-labour must always predominate, just as it did a generation since; but in the latter skilled labour can be eliminated, often to the extent of from 50 to 75 per cent. Again, a shop casting in loam cannot possibly dispense with highly skilled labour, while one making railway chairs, or other plain castings in green sand, need employ no skilled labour at all in such departments of work. The wide question of utilising moulding machines, to the exclusion of trained moulders, must therefore be always considered, not in the abstract, but in direct relation to the products of each individual shop. The modern manager must take a broad and intelligent view of the requirements of his own particular department in settling this important question. It is clear from the foregoing remarks that in some shops the moulding-machine is by far the most important aid to economy, while in others it is of little, or, perhaps, no value. In the great majority of instances, however, foundries may utilise these machines for certain sections of their work, while the remainder must be done by skilled craftsmen.

The proper sphere for moulding-machines is in work that is of a repetitive character; they score most heavily when hundreds or thousands of similar castings are required; but their use is often economical where

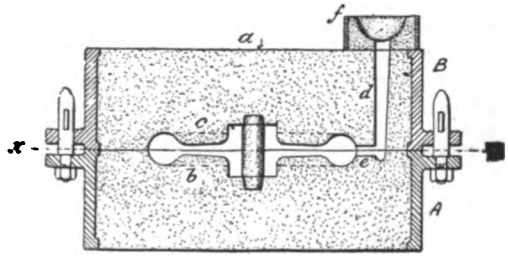

FIG. 1.—DIAGRAM TO ILLUSTRATE METHOD OF MOULDING BY TURNING OVER.

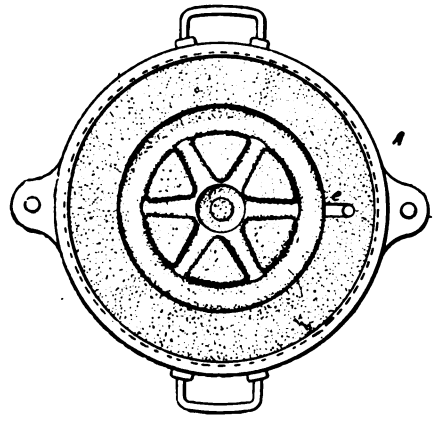

FIG. 2.—PLAN OF BOX A (FIG. 1) ON JOINT FACE *x*—*x*.

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twenty or thirty castings only are wanted—a fact which a good many foundries yet fail to appreciate. It is important to remember that economy can best be secured by the installation of different kinds of machines, and the adoption of different systems of moulding adapted to the different classes of work to be performed; for, in truth, moulding-machines have now become as highly differentiated as any of the great typical groups of machine tools. Further, dimensions now impose scarcely any limit to the utility of these machines, for patterns up to 10 feet or more in length are readily moulded by machines designed specially for the purpose.

For a student to grasp the full significance of the changes which are being wrought in these directions, some explanation of the conditions which govern the construction of moulds, and the devices which have led up to moulding machines, becomes necessary. The following diagrams will render clear some of the leading features in moulding, regarded from the particular point of view which relates to economy in labour.

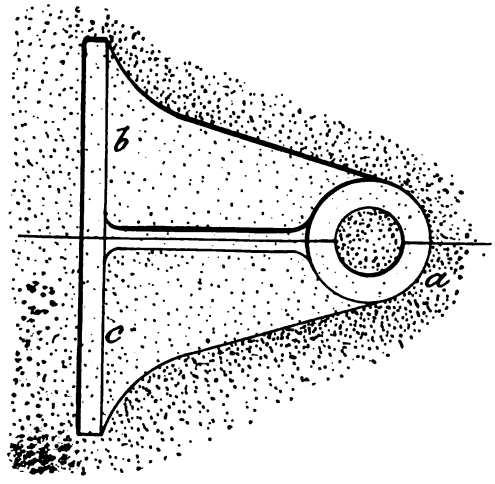

FIG. 3.—SECTION THROUGH MOULD OF A BRACKET, TO ILLUSTRATE EASY AND DEEP DELIVERY.

Figs. 1 and 2 illustrate the mould of a simple hand wheel, Fig. 1 showing the complete mould in vertical section, and Fig. 2 a plan of its bottom box A, thrown open by the removal of the top box B, and the withdrawal of the pattern.

In making this mould by the ordinary hand method, a false mould has first to be formed in the box B, its face, *a*, being laid on the ground or bench while the pattern is bedded into the sand enclosed by B. This is a temporary mould, the sole necessity for which lies in the fact that the pattern must be set in it until its central plane corresponds with the joint *x*—*x* of the box. The sand is levelled and smoothed in that plane, to make a joint face on which the sand in the box A is next rammed, over the projecting portion *b* of the pattern, thus forming the first portion of the actual mould. A and B are then turned over into the position which they occupy in Fig. 1. B is next removed, and its temporary body of sand is knocked out. It is then replaced and rammed over A to form its section of the mould next the face *c* of the pattern. At the same time a "runner," or "ingate," or "git" stick has to be inserted, to form, on its withdrawal, the pouring passage *d*. Thus there are three distinct and separate rammings required in any mould made by this process of "turning over," and three handlings of the box parts, in addition to the making of a joint face *x*—*x* carefully by hand. Even when these operations have been completed the mould is not finished. The box B has to be lifted off A by the handles seen in Fig. 2, the pattern has to be withdrawn from A by hand, and a runner *e* has to be cut. Generally, too, some broken-down sand will have to be mended up. Finally, the boxes must be closed and cottared, and the pouring basin *f*, made and put in place over the ingate.

These operations must be gone through in the case of every hand mould that is produced by the process of "turning over." In the case of "bedded-in" moulds, the temporary work done in the box B is saved. But the making of the bed-mould, and the jointing, often entail more work than when turning over is practised.

Further, the simple example illustrated by Figs. 1 and 2 does not show the disadvantages of hand work nearly so forcibly as many others would do. The objections to hand work are not limited to the loss of time occupied in ramming by hand; in fact, many modern moulding machines involve hand ramming. The objections to hand moulding relate far more to such matters as the making of joint faces, the removal of patterns from the mould, and certain minor details which, in the aggregate, make a strong case against hand work.

A glance at the section of the mould in Fig. 1 shows that there would be no particular difficulty in effecting the separation of the

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mould and pattern; but compare that with Figs. 3 to 6, in which sections are taken through moulds of brackets of considerable depth.

Taking Fig. 3, it is obvious that the conditions would be more favourable for clean delivery around the boss *a*, than next the deep feet *b* and *c*, since the frictional contact of the hard-rammed sand against the perpendicular faces causes the sand to become torn up more or less during the withdrawal of the pattern from the mould. This is seen in Fig. 4, where one-half the pattern is shown partly withdrawn. The semicircular section clears the sand at once at *a*, *a*, but the foot or flange remains in close contact with it at *b*, *b*. There is always, therefore, a risk of the sand being fractured diagonally at *c*, *c*; due, not only to the close contact between the pattern and the sand, but to the difficulty of lifting the pattern vertically and steadily by the hands—a difficulty which increases with the dimensions of the pattern. To obviate this, a considerable amount of "taper" or "draught" is imparted to deep perpendicular portions (compare Fig. 5), and the pattern is "rapped" or loosened before removal. On the other hand, an excessive amount of taper is objectionable, since it interferes with the subsequent fitting of castings. In spite of these provisions, "mending up" has to be resorted to in most moulds from which the patterns are withdrawn by the unassisted hands.

Turning to Fig. 6, we find a type of another class of moulding, where a deep portion—the boss *a*—comes in the top box. Now the top box must be either lifted off from *a*, which is fastened to the lower portion of the pattern, or *a* must be attached loosely with dowels to the lower part of the pattern, so that it lifts up in the top box, and is withdrawn therefrom after the turning over of the box. In the first case fracture of the sand is sure to occur if the withdrawal is by hand; in the second, it is avoided, but there is then risk of slight inaccuracies in the relations of the loose piece to the pattern body, which would show as a lap joint, or fault, in the casting.

The above, also, are examples of patterns moulded singly. Every pattern, small as well as large, has to receive the same detailed treatment, no matter how many similar castings are to be made. Thus we have a cumulated expenditure of labour, making in some kinds of work a very serious aggregate. I have not stated the whole of the case against hand moulding, some details of which would be rather too advanced for present consideration; nor complicated the argument by references to cores, loose pieces, work involving three-part boxes, and work with irregularly shaped joints, all of which would render the case still stronger against hand moulding. Nevertheless we have seen quite enough to justify the condemnation of the system when applied to a considerable proportion of the work of the foundry. Let

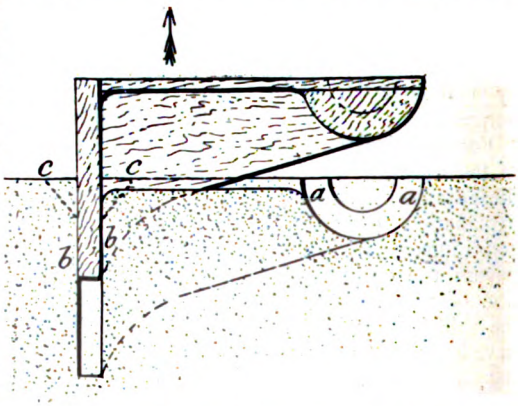

FIG. 4.—PATTERN DESTITUTE OF TAPER BEING WITHDRAWN FROM MOULD.

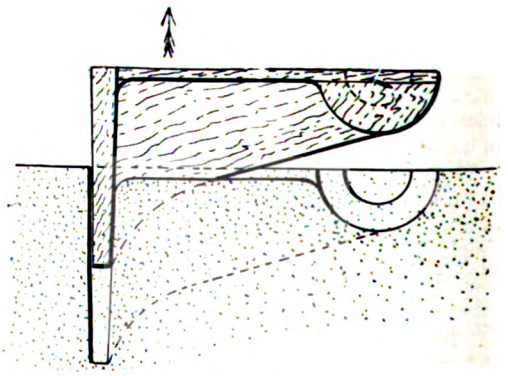

FIG. 5.—TAPERED PATTERN BEING WITHDRAWN FROM MOULD.

us now see how economy in labour can be secured, as well as increased accuracy in results.

The first economy is to make a permanent joint face in connection with the pattern, in order to avoid the ramming of the false mould in the box B, Fig. 1, and the laboured preparation of the sand joint for subsequent work. At the same time, when practicable, provision is made for producing more than one mould in a single box. These economies are not necessarily associated with machine

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moulding; they are largely adopted when hand moulding is practised, and so form an intermediate stage in the evolution of machine moulding.

The prototype of the device of a permanent joint has long been used, and is still employed in most foundries, namely, the "bottom board," or "joint board." Such boards are made to suit moulding boxes of various dimensions, to save the labour of preparing the sand joint in a temporary mould, while the waste of time of the latter device is avoided altogether. Such boards are either plain or recessed. A pattern like Fig. 7, which only requires a "plain top" in the mould, would lie flat on the surface of a board, and the first sand joint would be rammed up on the face *a*. Patterns for moulds like Figs. 3 and 6 would, if jointed, lie with their joint faces on plain boards. Solid (*i.e.*, unjointed) patterns require recessed boards, as in Fig. 8; this device is employed most extensively by brass moulders. In such a method the sand joint rammed on *a* belongs to the bottom box A, Fig. 1, and on this B is afterwards rammed.

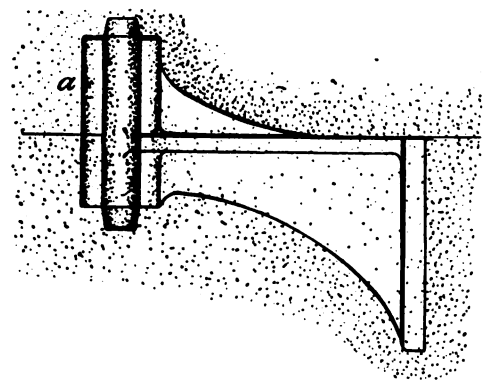

FIG. 6.—SECTION THROUGH MOULD OF A BRACKET, TO ILLUSTRATE A DEEP LIFT IN THE TOP.

Figs. 9 and 10 show a more advanced and permanent arrangement. Four patterns of the hand-wheel in Fig. 1 are shown attached to a metal plate, A, planed or ground truly on both faces; hence the term "plate-moulding" applied to this system. With the arrangement shown, moulding is still done by hand, but the advantages over the method of Fig. 1, as well as those over Figs. 7 and 8, are very substantial. The ramming of the false mould in Fig. 1 is saved, and so is the formation of the joint face, which is produced directly against the faces of the plate A. Neither have the ingates to be cut in the mould, for the patterns of these are put on the plate at *a*, *a*, *a*, *a*. Finally, four patterns being mounted, four moulds can be made, and poured at one time. These advantages can also be secured by the bottom or joint boards in Figs. 7 and 8; but in Figs. 9 and 10 there is added the important benefit of permanence of form, which cannot be secured by the use of timber. The metal patterns are riveted through a metal plate, and ten thousand moulds could be taken therefrom with the certainty that the last castings would not vary in form or size from the first.

This type of plate is used on ordinary moulding boxes. One box pin fits the hole *b*, the other in *c*, fitting sideways only in the latter, to accommodate minute differences in the centres of the pins of different boxes. The slot holes *d*, *d*, are provided for lifting the plate by.

Such a plate is suitable for use on a machine as well as for plate moulding. The only alterations required would lie in the methods of fitting to adapt it to any particular machine, none being necessary in the actual mounting of the patterns on the plate.

The remark has been made that the formation of joints by hand often occupies much time. The reason is that many joints are of irregular outlines. In Figs. 1-6 the joints are plane, and relatively easy to produce; but in a dished hand-wheel, such as Fig. 11, the sand joint must be dished also to follow the central plane, *a*, *a*, of the arms, and this would occupy much more time than the level one in Fig. 1. If, therefore, the wheel in

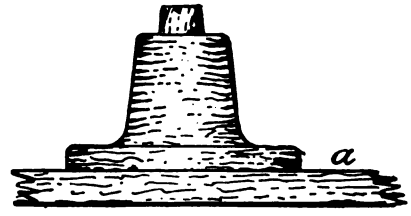

FIG. 7.—A PATTERN LAID ON A BOTTOM BOARD TO BE RAMMED.

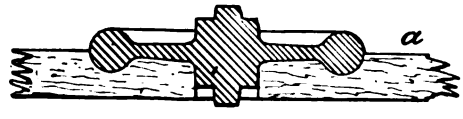

FIG. 8.—A PATTERN RECESSED INTO A JOINT BOARD FOR THE RAMMING OF ONE FACE.

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Fig. 11 were mounted on a plate, as in Fig. 12, the plate would be dished in the manner indicated by the curves, in continuation of the faces *a*, *a*. The thickness of the plate has, of course, no effect on the finished mould. In this case the wheel patterns would be cast with the plate as shown, in preference to riveting them, as in Figs. 9 and 10, or screwing them, as is often done.

Though the economies of Figs. 9 and 10 are very marked over those in Fig. 1, yet something more is desirable in the case of moulds of the types shown in Figs. 3 and 6, due to the difference in the "depth of lift." Putting such patterns on plates, and fitting the plate in a machine, the unsteady action of the hands during withdrawal can be supplanted by the perfect guidance of the machine slides, and thus "taper," and "rapping" can be reduced to a minimum or practically eliminated. This indicates one of the most pronounced advantages of machine over hand moulding. Mechanical withdrawal, an apparently trifling matter, is really of first importance

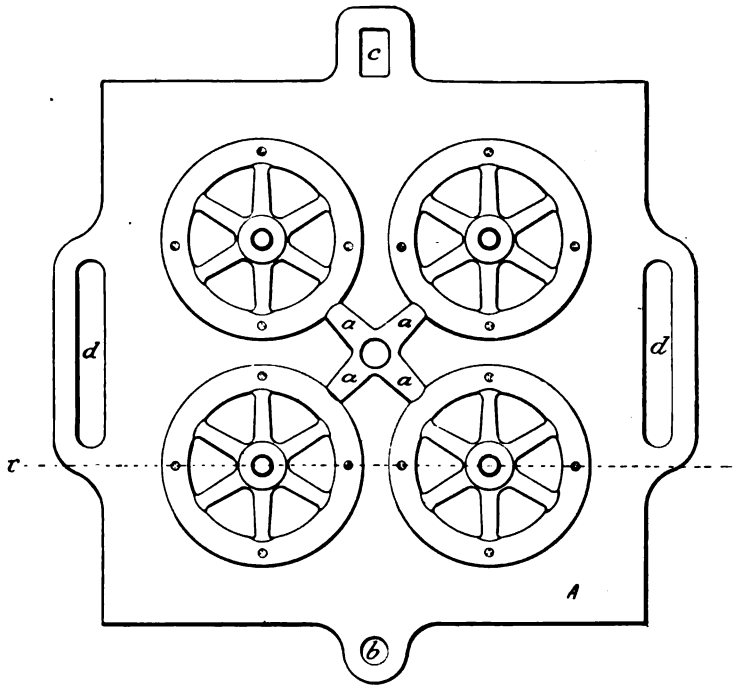

FIG. 9.—FOUR PATTERNS MOUNTED ON A METAL PLATE SUITABLY FOR PLATE MOULDING, OR MACHINE MOULDING.

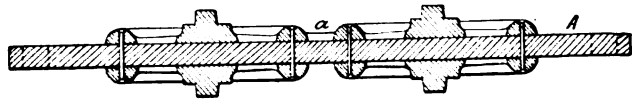

FIG. 10.—SECTION THROUGH *x*—*x* (FIG. 9).

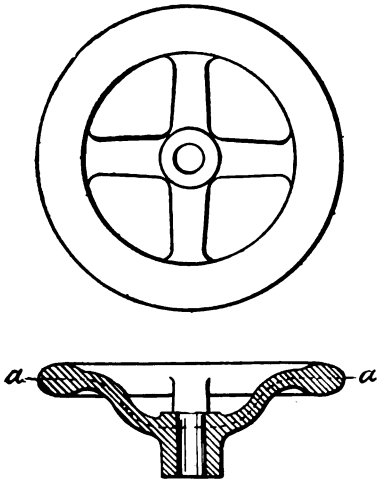

FIG. 11.—HAND WHEEL WITH DISHED ARMS.

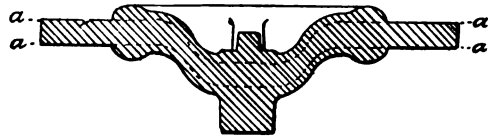

FIG. 12.—AN ILLUSTRATION OF IRREGULAR JOINTING.

Fig. 13 shows one pattern, and Fig. 14 the other, for Figs. 3 and 6 respectively, mounted on plates. The mechanism by which withdrawal is effected varies in different

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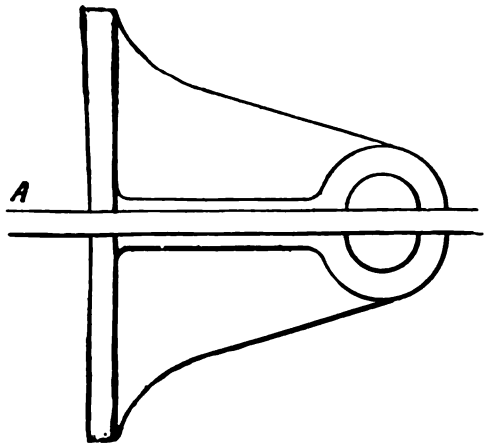

FIG. 13.—PATTERN OF BRACKET MOUNTED ON A PLATE.

machines, but it may be summarised briefly as follows :—

The plate A, in Figs. 13 and 14, may be mounted in a machine on trunnions, and each side rammed in turn. Then, while the plate is being jarred with a wooden mallet, the box parts may be withdrawn from the pattern parts in turn. Alternatively, the patterns may be lifted, or lowered away from the box parts. The result is the same in either case—a mechanical withdrawal, absolutely perpendicular, and without unsteadiness of movement.

Once more, as "depth of lift" is a relative matter, the necessity frequently arises for maintaining pressure on the sand in deep moulds, where overmuch jarring would have a disruptive effect on the sand. This is effected by a "stripping plate," a sheet of metal which encircles and fits the pattern closely, and through which the pattern is withdrawn. Fig. 15 illustrates a simple case, that of a gear wheel pattern, A, coming through a stripping plate, B.

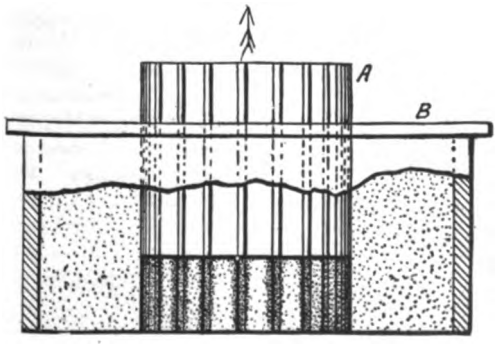

FIG. 15.—GEAR PATTERN BEING WITHDRAWN THROUGH A STRIPPING PLATE.

These remarks comprise as much as the limit of an article permits on this subject. The net results may be summarised as follows. Machine moulding is eminently adapted to small patterns, from which large numbers of castings are required. The device of Figs. 9 and 10 is capable of much extension, as many as twenty patterns or more, either of similar or of unlike forms, often being united and mounted on a single plate. Frequently, too, each half of a pattern is mounted on its own separate plate, and then the moulding may be done in separate machines by separate men, one doing tops, the other bottom parts. Large patterns may also be plated and moulded by machine, the parts being on the same, or on separate plates. And by employing a stripping plate there is no difficulty in the case of deep patterns in which hand moulding yields the most unfavourable

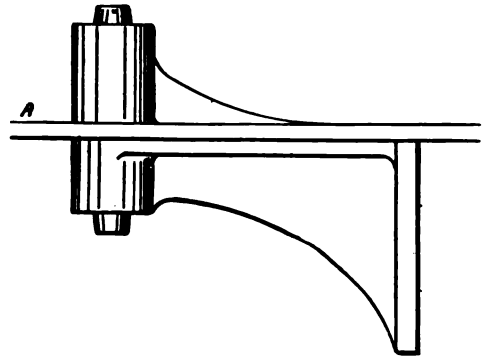

FIG. 14.—PATTERN OF BRACKET MOUNTED ON A PLATE.

results, due to taper, rapping, and mending up. "Multiple moulding," or the pouring of moulds superimposed, is a recent device for economising the floor area of foundries where machine moulds are made.

Machine moulding is adapted to the employment of power. Many machines, probably the majority, are hand operated, levers being the actuating mechanisms; but compressed air, steam, and hydraulic power are largely employed. The latter is adapted to many of the biggest machines, for turning out massive moulds, whether of single large castings, or those in which the dimensions are due to the multiplication of smaller castings produced from a single pattern plate.

The developments of machine moulding are effecting changes in moulding boxes: first, in improved fittings of the ordinary boxes; and, second, in the growth of

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"snap flasks." The latter are hinged boxes, from which the moulds are removed for casting. Their employment is due to the enormous output of the moulding machines, a single one of which is capable of producing some hundreds of moulds in a day. This makes large demands on the stock of moulding boxes, when several machines are in simultaneous operation in a shop. The snap flasks solve the difficulty by permitting the removal of the moulds from the flask for pouring, leaving the flask free for making another mould, which is in turn removed when finished, and so on.

The economy of the snap flask can be best appreciated by comparing Figs. 16 and 17 with Figs. 1 and 2. In Fig. 16, the flask is shown complete with a pattern of a trolley wheel on its plate A, and top and bottom moulding boards lying in their correct relations to the flask. Fig. 17 shows the flask partly open to permit of the removal of the mould, which is carried away on the bottom board, B, covered with the top board, C. Weights are loaded on the latter to keep the mould closed during pouring. The drawings are self-explanatory, illustrating corner plates, hinges, "snap," or latch fittings, concave recesses to prevent the mould from dropping out while being lifted, and triangular pins, with adjustable holes by which a perfect fit can always be secured, so that the pins will not wear slack, and thus allow the box parts to move in relation to each other. "Multiple moulding" is adopted in connection with these flasks.

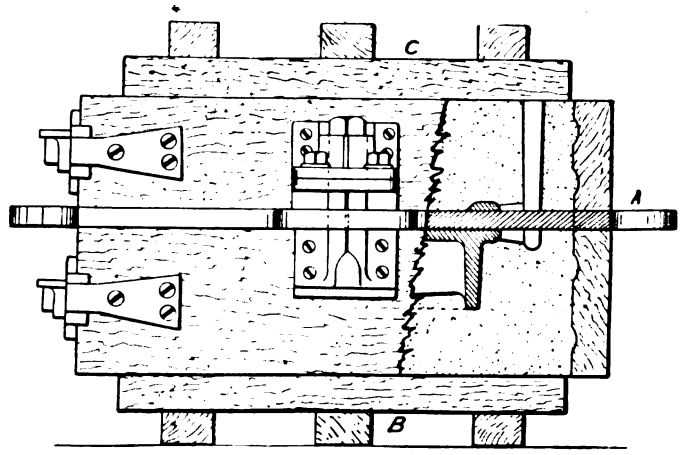

FIG. 16.—A SNAP FLASK, ENCLOSING THE PATTERN OF A TROLLEY WHEEL.

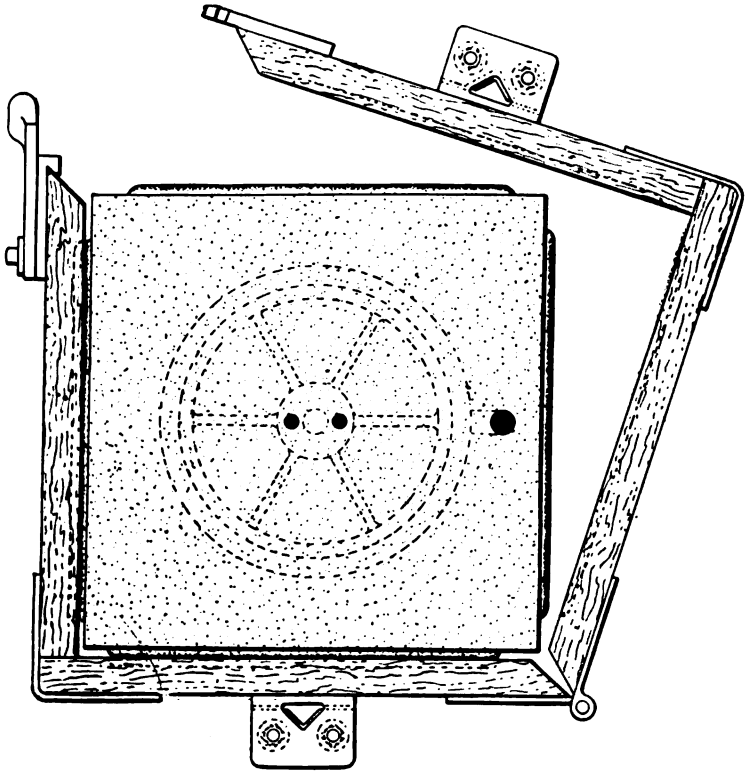

FIG. 17.—SNAP FLASK BEING OPENED TO PERMIT OF THE REMOVAL OF THE MOULD.

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ELECTRO-CHEMICAL AND ELECTRO-METALLURGICAL INDUSTRIES.

PART I.—ALUMINIUM.

By JOHN B. C. KERSHAW, F.I.C.

THE BRITISH ALUMINIUM COMPANY'S WORKS AT FOYERS, SCOTLAND. THE OVERFLOW FROM THE DAM.
Photo by D. Whyte.

Introduction

THE manufacture of aluminium on an industrial scale by aid of the electric current dates from 1886, in which year the Brothers Cowles commenced to manufacture ferro-aluminium and aluminium alloys at Lockport in America, and at Milton in Staffordshire, England. These two works were operated until 1892, but pure aluminium could not be produced by the Cowles process; owing to this fact, and to the rapid fall in price of the new metal, as a result of the successful operation of the Hall process in America and the Héroult process in Europe, the Lockport and Milton works were shut down in the latter year.

Several other processes for the production of aluminium by electrolytic or electro-thermal methods have been tried experimentally since the Cowles works were started in 1886, but only two of these have survived the competition which has resulted amongst the various processes; and at the present time the whole of the world's output of aluminium is produced either by the Hall or by the Héroult process. The most striking failure occurred in connection with the development of the Webster and Castner process at Oldbury, Birmingham, by a company floated with a large capital, in 1887, and named the Aluminium Company. This process was not dependent upon the use of the electric current, since the reduction of the metal was effected by the action of metallic sodium upon a mixture of aluminium fluoride and chloride at a red heat.

A fine works was erected by the above company at Oldbury, near Birmingham, and in 1888, when manufacturing operations were started, a prosperous future was anticipated for the process and company which operated it. Three years later, in 1891, the Oldbury works had to suspend the manufacture of aluminium by the Castner and Webster process, for the Héroult process in Europe and the Hall process in America had been developed upon an industrial scale; and the figures in Table I. show how rapidly the price of aluminium fell as a result of the competition of the two new processes.

Limits of space will not permit the writer to follow in detail the industrial development of the aluminium industry from 1890 down to the present date. As already pointed out, all the aluminium produced is now

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manufactured by the electrolytic processes, and although the industry has not developed to such large proportions as was expected in its early days, the annual output of the metal is now about 8000 tons. The number of works engaged in the industry is nine, situated as follows:—

America, 3; France, 2; United Kingdom, 1; Germany, 1; Switzerland, 1; Austria, 1.

The gross horse-power available for the manufacture in these nine works is equivalent to about 40,000 horse-power; and were the whole of this power devoted to the production of aluminium, an output of 11,500 tons per annum might be produced.

When one recalls the fact that down to 1886 aluminium was practically a laboratory curiosity, and was sold at 3*s.* 6*d.* per ounce, the progress made during the last fifteen years, in cheapening the metal and rendering it available for use in the arts and industries, is certainly remarkable.

In the following table the figures for the total world production in tons, and average value per pound in pence, year by year since 1885, have been gathered together. The two sets of figures form a striking commentary upon the practical benefits that have followed the application of electrical methods to this industry.

The details of the chief processes for the production of aluminium by aid of electricity, which have been employed during the last fifteen years, will now be described.

The Cowles Process

The Cowles process of aluminium production, which was worked upon a fairly large scale in England and America during the early days of the industry, depended upon the reducing action of carbon upon alumina. (Al_2O_3) at a red-heat. The process was electro-thermal and not electrolytic in character, the electric current being employed merely as a heating agent. The reduction of alumina by carbon alone is not possible, in the absence of any metal with which the aluminium, when reduced, can alloy itself; for aluminium, at all temperatures, has a greater affinity than carbon for oxygen. But, in the presence of copper or iron, the reduction of alumina by carbon is practicable in the electric furnace, since the affinities of the two metals, and their disposition to form an alloy, render the aluminium more ready to part with its oxygen. A study of the heat of formation figures for alumina, carbon dioxide, and the aluminium alloys is instructive, and throws light upon the reduction of alumina in the electric furnace; but limits of space will not permit the writer to deal with

TABLE I.

WORLD'S PRODUCTION OF ALUMINIUM IN METRIC TONS, AND AVERAGE PRICE PER LB. IN PENCE, IN EUROPE AND U.S.A. YEAR BY YEAR SINCE 1885.

		1885	1886	1887	1888	1889	1890*	1891	1892	1893	1894
Total Production in tons .		3	14	22	39	85	174	324	485	713	1057
Price in pence per lb.	Europe .	600	498	399	249	—	100	25‡	32	—	25
	U. S. .	—	—	—	—	125	—	25‡	32	37	27

TABLE I.—*continued.*

		1895	1896	1897	1898	1899	1900	1901	1902	1903
Total Production in tons .		1129	1789	3394	4033	6570	7338	7571	8000†	8000†
Price in pence per lb.	Europe .	18	16	—	—	—	—	—	—	—
	U. S. .	26	21	17·5	16·25	16·0	15·5	15·5	15·2	—

* Electrolytic manufacture commenced. † Estimated. ‡ Fall in price due to sales of electrolytic aluminium.

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these figures here, and he can only recommend students of the subject to look them up.

The Cowles process, as carried out at Milton in Staffordshire, consisted in heating powdered corrundum (a form of alumina—Al_2O_3) with charcoal in the coarsely-powdered state, and filings of iron, in a large electric furnace, lined with charcoal coated with lime. The current used for heating this furnace was one of 5000 amperes at 60 volts, and the passage of this current through the charge of oxide and carbon, caused intense heating. The furnace was kept in operation for one-and-a-half hours, and the output from this furnace, in the early days of the industrial trials, was stated to be one pound of metal per 18 horse-power hours. It is interesting to note that at this date (1888) the dynamo at Milton was the largest generator yet built in any country, and this 300 kilowatt machine was visited and inspected by many engineers, and was regarded as a notable triumph in electrical engineering work.

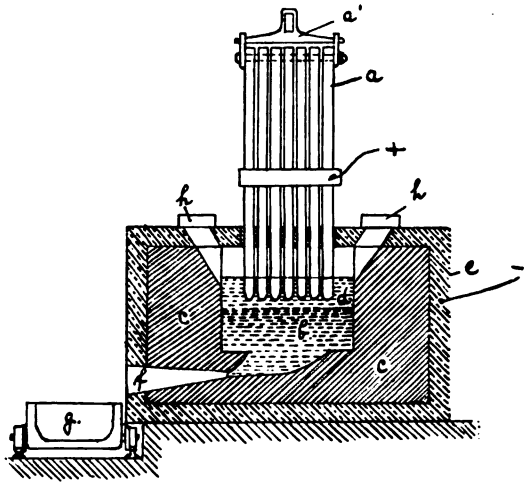
A similar furnace was in operation at Lockport, U.S.A., from 1886 to 1892; but, as already stated in the Introduction, owing to the rapid development of the Hall and Héroult processes, and to the inability to produce pure aluminium, the Cowles process ceased work in the latter year.

The Hall Process

The Hall process of aluminium reduction has been operated in America since 1888. It is at present employed at three works in that country, disposing of 16,000 horse-power, while a fourth works is now in course of construction. The Hall process is also employed at one of the European aluminium works, situated at Calypso, near St. Michel, in France. All of these aluminium works are operated by water-power.

In the Hall process a fused electrolyte composed of cryolite, fluor-spar, and alumina is electrolysed.

Cryolite is a mineral containing aluminium fluoride and sodium fluoride, while fluor-spar is a crystalline variety of calcium fluoride. When these three compounds are melted together, the alumina dissolves in the mixture of fluorides, and if an electric current be now passed through the mixture, using carbon as electrode material, aluminium is separated in the molten state at the negative pole. As originally carried out, Hall used a carbon-lined crucible for containing the electrolyte, and heated this externally. It was, however, found much more convenient to utilise the current for melting and keeping the electrolyte at the desired temperature, so that external heating of the crucibles or pots was discarded very early in the development of the process. The alumina is alone decomposed by the current, the fluorides of aluminium, calcium, and sodium remaining unaltered in the bath, and serving merely as a solvent for the oxide of the metal. Aluminium in the molten state is heavier than the molten mixture forming the electrolyte, and falls to the bottom of the decomposing bath—a circumstance of considerable importance to the successful conduct of the process. The oxygen liberated at the anode combines with the carbon and forms carbonic acid gas (CO_2), and since a very pure form of carbon is essential for the production of pure aluminium, the cost of



THE HÉROULT ALUMINIUM BATH—ORIGINAL FORM.

a, anodes; *a'* anode carrier; *b*, molten alloy; *c*, carbon blocks (*b* and *c* function as kathode); *d*, electrolyte; *e*, iron casing; *f*, tapping hole; *g*, casting trough; *h*, charging holes.

anodes forms an important item in the total cost of production.

Professor Richards has given the following details of the operation of the Hall process at Niagara Falls. The baths are of sheet-iron lined with carbon, and are oblong in shape. The current passes into each bath or "pot" by carbon electrodes, each three inches in diameter and eighteen inches in length, suspended from a copper carrier bar running longitudinally over the bath. The "pots" are worked in series, and the drop of potential at each "pot" is 5 volts. Each "pot" absorbs about 65 horse-power, and produces about 112 lbs. aluminium per twenty-four hours. The electrolyte is kept at the necessary degree of fluidity (850°—900° C.) by the

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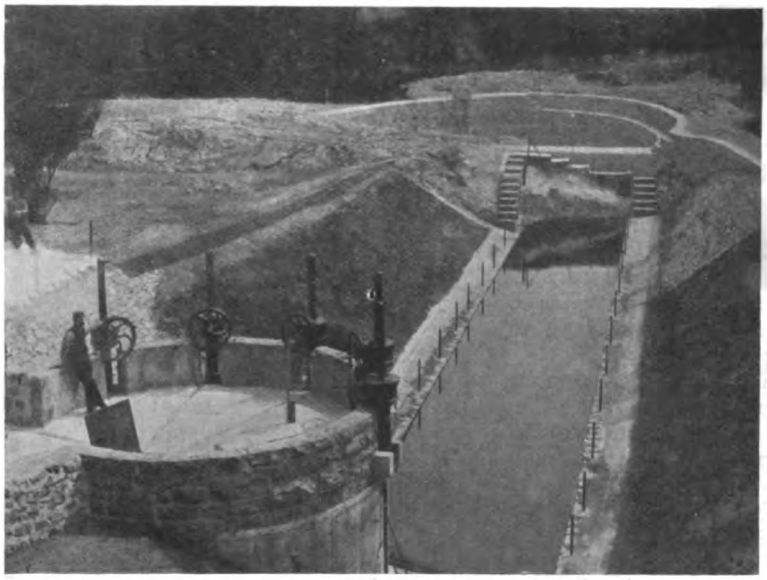
action of the current, and about one-half of the energy of the electricity is required for this purpose, the other half performing the actual electrolytic dissociation of alumina into the metal and oxygen. Alumina is added to the "pots" at regular intervals, as that dissolved in the electrolyte is decomposed, and the surface of the electrolyte is kept covered with powdered coke to prevent loss of heat by radiation.



British Aluminium Company's Works, Foyers, Scotland
Entrance to Tunnel of Power Supply.

The annual production of aluminium by the three works operating the Hall process in America is now about 4200 tons, and the manufacture is still growing. It is interesting to note that Mr. Hall, the inventor, was still a student at college when struck with the possibilities of the process, and that the leading details of it were worked out, and a patent was applied for, before Mr. Hall had completed his twenty-third year.

The Héroult Process

The Héroult process of producing aluminium from alumina is employed at five of the six European works, and is so similar in all respects to the Hall process that one is surprised to find distinct patents and organisations in existence for the two processes.

The process was worked out by M. Héroult, a French metallurgical chemist, in the years 1886–88, and manufacture upon an industrial scale was commenced at Neuhausen, in Switzerland, in the year 1889.

Until 1891 only copper aluminium alloys were produced by the Héroult process at this works, but improvements made in it by Kiliani rendered the process suitable for the manufacture of pure aluminium, and since 1891 this has been the chief product at Neuhausen, and at the four other European works.

In the original patent specification an iron vessel thickly lined with carbon blocks was described, and the walls of this were used as the negative electrode exactly as in the Hall process. A bundle of carbon rods or plates was suspended over this vessel, and functioned as the positive electrode of the electrical circuit, and the electrolyte was composed of fused alumina without any other admixture.

Molten copper was however used on the floor of the bath, and the aluminium, separated from the Al_2O_3 by the action of the current, at once united with this and formed aluminium bronze. The electrolyte was kept in the molten state by the action of the current, and external heating does not appear to have been used at any stage in the development of the Héroult process. The modifications introduced into the Héroult process since 1889 relate to the composition of the electrolyte, and as now carried out at Neuhausen, La Praz, Foyers, and elsewhere, it is practically identical in principle and operation with the Hall process. It is interesting to note that Hall's first American patent for aluminium production is dated 1886, while Héroult's first French patent for the same manufacture is dated 1887. Each inventor was at that date unaware of the other's experimental work, and both appear to have arrived independently at the same solution of the problem which they had attacked. The English company which operates this process commenced the manufacture of aluminium at Foyers in

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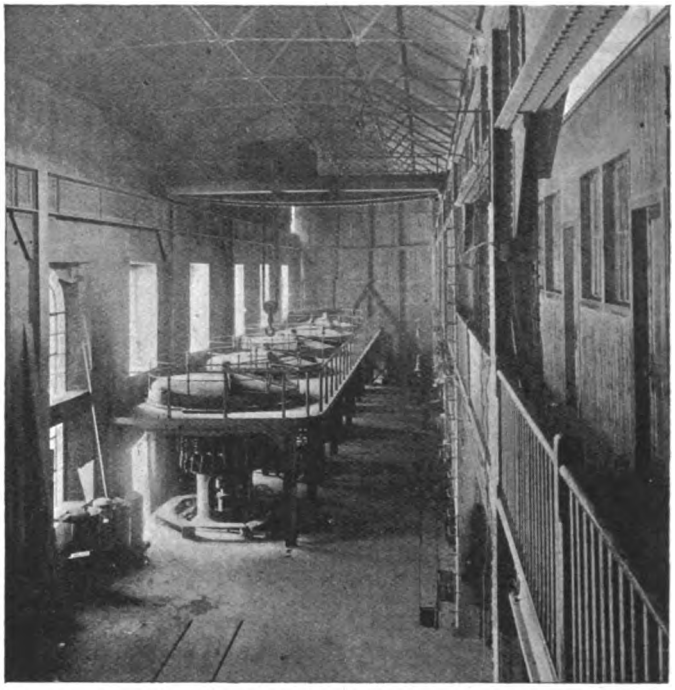
1896, and a great outcry was made at that time concerning what was called the desecration of one of the most beautiful falls in North Britain. Very large hydraulic engineering works were erected, and 14,000 horse-power were rendered available for manufacturing operations.

The original installation of electrical generating machinery was equal to 3500 horse-power, but extensions are now being carried out at Foyers which will bring this total up to 5600 horse-power.

The views illustrating the Foyers works are from photographs kindly placed in the writer's hands by the British Aluminium Company, and they prove that the damage done to the beauty of the locality has been less serious than was anticipated when the works were projected.



THE BRITISH ALUMINIUM COMPANY'S WORKS, FOYERS, SCOTLAND. THE DYNAMO HOUSE.

The other works producing aluminium in Europe by the Héroult process, are situated at Neuhausen, Rheinfelden, Lend-Gastein, and La Praz, and in the aggregate they have 22,000 horse-power available for the manufacture. Each of these works, with the exception of that at Neuhausen, is however engaged in other manufactures, and a varying proportion of the total power available is devoted to the production of aluminium. Estimates of aluminium production, based on the horse-power available, are therefore misleading.

In Table II. the more important facts and figures relating to the industry are gathered together, and these will doubtless prove useful for reference purposes.

It may be advisable to point out that the

TABLE II.

DETAILS OF ALUMINIUM WORKS IN EUROPE AND AMERICA.

No.	Name of Company.	Locality of Works.	Horse Power.		Process.
			Available.	In use.	
1	The Pittsburg Reduction Co.	Niagara Falls	} 10,000	{	Hall.
2	The Pittsburg Reduction Co.	Niagara Falls	}	{	Hall.
3	The Northern Aluminium Co.	Shawinigan Falls	6,000	(?)	Hall.
4	The British Aluminium Co.	Foyers	14,000	5,000	Héroult.
5	Société Electro-Metallurgique Française	La Praz	12,500	5,000	Héroult.
6	Compagnie des Produits Chimiques d'Alais	St. Michel	6,000	2,000	Hall and Minet
7	Société Anonyme pour l'Industrie de l'Aluminium	Neuhausen	4,000	4,000	Héroult.
8	Société Anonyme pour l'Industrie de l'Aluminium	Rheinfelden	5,000	5,000	Héroult.
9	Société Anonyme pour l'Industrie de l'Aluminium	Lend Gastein	5,000	(?)	Héroult.

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purity of the metal obtained by the electrolytic process has steadily improved, and that the product now placed on the market contains on an average 99·6 per cent. Aluminium. This improvement has been due to the recognition of the fact that the impurities of the raw materials used in the process collect in the reduced metal, and that the purity of the latter therefore depends upon the purity of the alumina and of the carbon which are consumed in the bath. In the early days of the industry insufficient attention was paid to this point, and aluminium containing 2 per cent. or more of silicon and iron was placed on the market.

Purity of the Metal

The alumina used in the electrolytic baths is obtained from a mineral called bauxite, which contains aluminium, silicon, and iron in the state of hydrates. Pure alumina is prepared from this by a chemical process, depending upon solution of the aluminium oxide in sodium hydrate. All of the aluminium factories now possess their own bauxite mines and refining plants for preparing the pure alumina. Hall has recently patented an electro-thermal process for treating the crude bauxite, which is expected to materially cheapen the cost of the refined alumina.

The preparation of the carbon electrodes for use in the baths also demands much care, and subsidiary plants for making these electrodes are employed by the British Aluminium Company at Greenock, and by the other aluminium extraction companies at various centres in Europe and America. The cost of producing aluminium by the electrolytic process is estimated to be about 1*s.* per lb., the various items of this total being made up as follows:—

Carbon Electrodes

Electrical energy	1·80 pence.
Alumina	4·50 ,,
Carbon electrodes	1·50 ,,
Labour and management charges .	1·50 ,,
Stores, etc.	·75 ,,
Interest, repairs and maintenance charges	1·75 ,,
Total . . .	11·80*d.* per lb.

It thus appears that raw materials (alumina, and carbon electrodes) account for one-half of the cost of production of aluminium, and that any reduction in the cost must come from this source, rather than from an improvement in the electrical efficiency of the process. A process which would permit crude bauxite to be used in the electrolytic baths would reduce the cost of aluminium production by 20 per cent. and yield a fortune to its inventor.

Aluminium is a white silvery metal of only 2·6 sp. gr., and most of its applications in the arts and industries are due to its extreme lightness, and to the fact that it does not tarnish on exposure to the atmosphere. Latterly a large amount of the metal has been consumed for metallurgical purposes, its application in these cases being based upon its great affinity for oxygen, and the high temperature attained when the combustion (or oxidation) is allowed to occur under favourable conditions. A few details regarding the more important applications of the metal are given below.

Characteristics of Aluminium

The electrical conductivity of commercial aluminium is between 55 and 61 per cent. of that of copper when wires of equal sectional areas are compared; but as the former metal is only one-third the weight of the latter, the costs of the two metals, for conductors of equal carrying capacity, are about equal, when copper is selling at £70 per ton in the form of wire bars, and aluminium is selling at £135 per ton, or 14½*d.* per lb. in the same form.

In the United States a large number of power transmission schemes have been equipped with bare overhead aluminium conductors: several hundreds of tons of the metal have been employed for this purpose, especially in the Western States.

Electrical Conductors

The reports which have appeared, concerning the present condition of these aluminium overhead lines in America, are on the whole satisfactory, the breaks which occurred in the earlier trials being now attributed to defective metal. One of the difficulties attending the use of aluminium for electrical conductors—namely, that of jointing it—has been overcome by the use of a mechanical sleeve-joint, in place of brazing or soldering the two ends of the wires. The most striking illustrations of the use of aluminium for power transmission in America, are between Niagara Falls and Buffalo, where an overhead line carrying 15,000 horse-power over twenty-two miles has been erected; and in California, where the North Yuba Power Company has an aluminium transmission line sixty-three miles in length in operation.

The use of aluminium as an electrical conductor has not progressed to a like extent in Europe; researches by Ditte in France, and the writer in this country, having thrown some doubts on the durability of commercial aluminium, when exposed to a humid atmosphere.

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The larger proportion of aluminium produced at the present time is probably employed for metallurgical purposes; and since the metal does not require to be specially pure for this application, a cheap grade of aluminium, containing up to 10 per cent. of iron, can be utilised.

As already pointed out, aluminium has a very high affinity for oxygen, and when mixed in the molten state with iron or steel containing small amounts of oxide, the aluminium robs the iron of its oxygen, and rises to the surface as a light scum of Al_2O_3. The metal is therefore used for putting into iron and steel crucibles at the moment of pouring, when castings of special fineness are required: very large amounts have been used in the iron and steel foundries of France, Germany, and England for this purpose. According to M. Héroult, 2500 tons of the lower grades of aluminium have been employed in this manner in the steel industry alone, and the consumption in this industry in France reaches 400 tons per annum.

Use of Aluminium for Casting Steel

Vautin discovered, and Goldschmidt of Essen has worked out, the details of another application of aluminium depending on this same property. If aluminium in the form of powder be mixed with granulated ferric oxide, and the charge be ignited, an intense combustion occurs: the aluminium combines with the oxygen of the ferric oxide, while the iron is reduced to the metallic state. The heat generated during this reaction is so great, that both the aluminium oxide and the iron are obtained in the molten condition at a white heat, and unless the crucible is of special make, this also may be melted in carrying out the operation. This mixture of powdered aluminium and ferric oxides is now being placed on the market under the trade name of "Thermit," and it is being largely employed for various purposes.

Thermit

Defective castings, broken main-shafts and stern-posts of steamers, and broken cog-wheels, can all be repaired in a very short time with thermit, the *modus operandi* being to form a mould round the broken parts, and to run the molten iron obtained from a suitable charge of thermit into this. The crucible is generally fixed above or close to the mould, so that no heat may be lost in the requisite transfer of molten metal. The iron obtained from a charge of thermit is at a white heat, and a true weld is obtained within the mould. The jointing of tramway rails for electrical purposes is also now being carried out by aid of thermit, and in Germany many miles of tramway track have been welded in this manner.

Alloys of iron or steel with aluminium, or with other metals, can be obtained by mixing the oxides in suitable proportions, and by adding sufficient powdered aluminium to carry off the whole of the oxygen. Chromium and its alloys are now being manufactured by the Goldschmidt process at Essen; and many of the more refractory oxides have been reduced in the laboratory by similar means.

The temperature attained in the Goldschmidt process is said to approach 3000° C., and Professor Zenghelis of Athens, by using oxygen in place of ferric oxide, is reported to have obtained the extraordinarily high temperature of 4000° C. by the oxidation of powdered aluminium. At this temperature platinum melts like glass: even the temperature of the electric arc is exceeded in the crucible which contains the aluminium powder.

A new application of aluminium, which promises to become of some importance, is its use as a substitute for stone in lithographic work. Aluminium plates with a suitably prepared surface are found to answer admirably for colour printing, and in America, England, and Germany a large number of the leading lithographic firms are now employing the new metal. The great advantages of aluminium as compared with stone, when used for colour printing, are its lightness and its adaptability to rotary presses. Both of these characteristics increase the speed with which work can be turned out; and as speed means money in these days, this use of aluminium in the printing world is certain to extend.

Use of Aluminium in Printing

Pure aluminium is a comparatively weak metal: in the form of wire its breaking strain is about 13 tons per sq. in., as compared with 30 tons for hard-drawn copper, and 35 tons for steel wire. For many purposes in which a greater degree of strength is required, aluminium is alloyed with other metals; and these alloys have a large field of usefulness. Aluminium bronze, Partinium (an alloy of aluminium and tungsten), Wolframinium (a similar alloy), and McAdamite (an alloy containing aluminium, zinc, and copper), may be mentioned as patented alloys, in which strength is gained by the addition of other metals. Magnalium is another alloy, in which aluminium is combined with magnesium, and this

Alloys of Aluminium

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alloy is unique in being lighter than the aluminium itself. Magnalium is stated to be of great value for the construction of the metallic parts of optical and other scientific instruments, since it can be worked well in the lathe, makes fine castings, and does not tarnish. A company has been floated in Germany for its manufacture.

Miscellaneous Uses

The use of aluminium for making small ornamental articles, such as match-boxes, photograph frames, etc., etc., is extending, and shops devoted to the sale of these goods are now common at most watering-places. The lightness of the metal, its silvery appearance, and its superiority to silver as regards tarnishing, are all points in its favour when applied to this class of work.

Aluminium cooking utensils are also being widely sold, and for this purpose aluminium is stated to be superior to copper or brass.

Army canteen outfits and camping equipments are being constructed of aluminium; the gain in lightness being held ample compensation for the increased first cost. Water-bottles of aluminium have also been supplied to certain regiments in the French and German armies, while aluminium helmets are receiving trial.

Aluminium has also been employed for constructing the frames of bicycles, but in this application no great degree of success has been attained. Some of the new flying-machines which have been experimented with during the last three years have also been constructed with aluminium rods or tubes. Here again it is questionable whether the application is wise, and whether bamboo would not be a safer material to employ. In motor-car construction aluminium alloys are reported to be much used, and, according to Héroult, this is now one of the chief uses of the metal in France. The use of aluminium for boat-building has proved a failure, and even the protected deck-plates of the yachts built for contesting the American Cup match have not shown any degree of durability. This corrosion of commercial aluminium by sea-water, and by sea-air, is attributed partly to the impurities which it contains and partly to the ease with which it enters into electrolytic action when in contact with other metals.

Aluminium is being used for large castings, as for engine cylinders, etc., where lightness is of importance, and where the tensile strength demanded is not high. At a foundry in Sunderland, where a special feature has been made of this branch, seventy-five men are reported to be employed in the aluminium casting-shop.

Use to form Explosives

One of the latest applications of aluminium is in the manufacture of a new explosive called "Ammonal." The great heat produced by the oxidation of aluminium powder is here made use of to raise the gaseous products formed by the decomposition of ammonium nitrate to a very high temperature. This increase of temperature intensifies the explosive effect on detonating the mixture. "Ammonal" is patented, and the manufacture is about to be commenced, either in this country or on the Continent.

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THE HEATING AND VENTILATION OF AN EDUCATIONAL BUILDING.

PART II.—VENTILATION.

By W. W. F. PULLEN, A.M.I.C.E., M.I.Mech.I., Wh.Sc.

HOWEVER well a heating system may work, there is still the problem of ventilation to be solved when a large number of people have to occupy a room, such as a class room or lecture theatre. In the case of private rooms for teachers' use, ventilation can generally be moderately well secured by means of the usual grids or gratings in the walls, which communicate with flues reaching to the top of the building. These grids alone are of very little use in crowded rooms, and can only be made to provide sufficient ventilation when some mechanical means is adopted to hasten the air through them. This can be secured by placing a fan in the flue itself, and thus inducing the current of air to move much more rapidly. But the air must come from some source outside the room, and generally from the outer air; hence the incoming current, except in the summer, will be so cold as to constitute a serious draught. It will also be necessary to have a number of fans in different parts of the building, which will require maintenance and supervision. The cold draught is the most serious objection that can be raised against this arrangement, but the objection is so serious that the system can only be used in very special cases, such as the ventilation of a chemical laboratory; and even here, it is not so efficient or economical as the system about to be described.

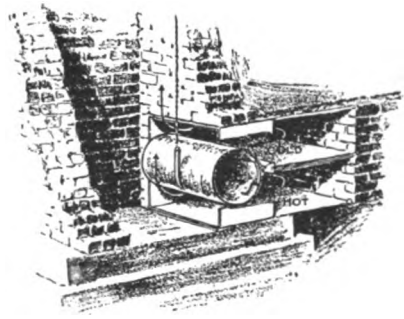

FIG. 5.—REGULATING DAMPER.

The hollow cylinder at the mouths of the hot and cold air ducts is hinged at its periphery to the dividing partition. A chain passes round it and up to the regulating handle. On pulling the chain the cylinder is lifted, and reduces the cold air outlet while it enlarges the hot air outlet, thus producing a warmer mixture.

If the incoming air spoken of above were warmed to such a temperature that the draught is no longer unpleasant, the chief objection to the scheme would be removed. A draught generally becomes recognisable by the passage of heat from the exposed surface of the body to the moving air. This is due to the quantity of air brought into contact with the body, and to the difference of temperature between the body and the air, and also varies with the humidity of the latter. If the air be sufficiently warmed before entering a room, what would otherwise constitute an unbearable draught becomes not at all unpleasant; and if the cross-section of the air-current, and the position of its entrance into the room, be properly arranged, the result is perfect ventilation and heating by the same means.

A human being requires about 30 cubic feet of fresh air per minute, and at least 250 cubic feet of air space should be allowed for each person in an ordinary class-room. Under these conditions the entire air of the class-room should be changed about every eight minutes, and this is what any good system of ventilation must accomplish.

In the best system for heating and ventilating by hot air, the heated air is propelled into the room through a large grating 8 or 9 feet from the floor. The grating is situated in one of the inner walls, and preferably in the one opposite to the outer wall containing the windows. The hot air tends to move slowly across the room, and on reaching the wall becomes slightly cooler and descends towards the floor. It then steadily returns to the outlet grating, which is at the floor level and in the same wall as the inlet grating. After leaving the room, the air passes up flues in the walls, into the atmosphere above the roof.

The temperature of the incoming air is regulated in the following manner:—Two parallel supply ducts or flues are built in the wall (Fig. 6), one being used to supply cool air at the atmospheric temperature, and the other to simultaneously supply hot air at a

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The fan in the basement draws in air near the main entrance, and delivers the hot and cold streams to the main horizontal ducts. The inlet and outlet gratings are shown in two of the rooms, but the connections to the vertical flues are best seen in the detailed section on the left, which is drawn to a larger scale. This also shows the main outlet damper which regulates the quantity of air passing out of a flue.

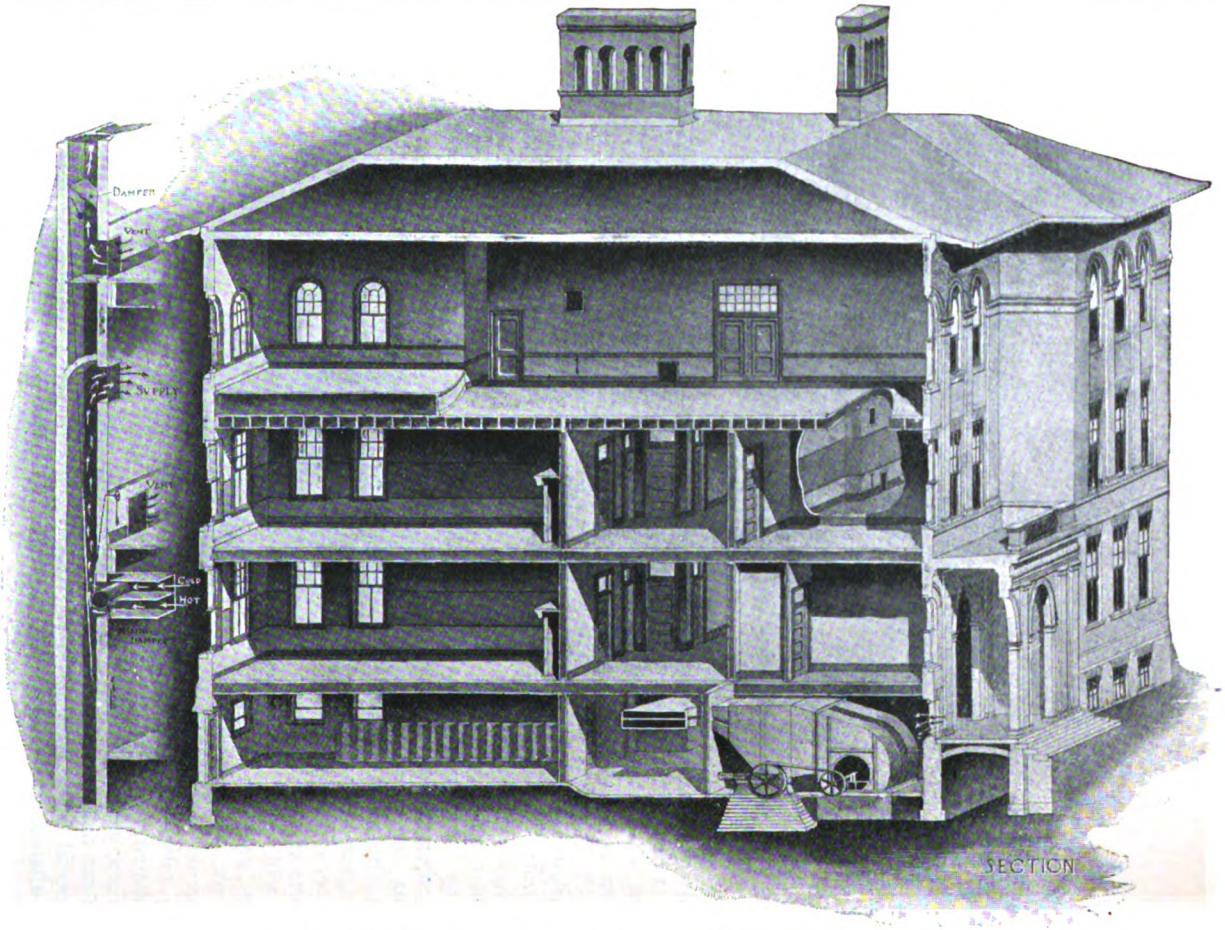

FIG. 6.--SECTION OF SCHOOL BUILDING FITTED WITH HOT AIR APPARATUS.

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temperature of about 120° F. Both ducts deliver into the same grating (Figs. 5 and 6), and the amount of air supplied through each is easily regulated by a special mixing damper operated by a chain or handle (Fig. 7). If the chain is pulled out to its extreme position, all hot air and no cold air enters the room, while in the opposite position only cold air is supplied. In any intermediate position a corresponding mixture of the two is delivered, the position of the chain indicating the relative quantities of each kind.

The air is propelled through the ducts by a fan situated in the basement of the building (Fig. 6). Part of the air delivered by the fan is taken direct to the cool air channels, while the remainder is made to pass over numerous coiled pipes, through which steam circulates. In this way the air absorbs heat from the coils at a practically constant temperature. The coils are connected to a steam boiler; if there are steam engines on the premises, their exhaust steam can be made to do duty in the coils, and so heat the air without involving extra cost while the engines are running.

It is customary in towns to use blanket filters, through which the air is made to pass on its way to the fan; and when a new building is designed to be heated in this manner, a well or huge flue is generally made, through which the air is conducted from above the roof to the fan chamber.

The filters, which are periodically renewed, prevent much of the usual dust from entering the building, and the air is thereby rendered as pure as the neighbourhood will permit.

The entering air is automatically humidified by keeping the filters periodically deluged with water from a sort of flushing tank. These filters, when damp, are much more effective than when dry. This system is best adapted to a new building, where it should be incorporated in the architect's designs, and the channels built in the walls; at the same time, it is readily applied to existing buildings by making ducts of sheet iron, and, where possible, decorating them so that their appearance shall be in harmony with their surroundings. Air trunks can sometimes be made to imitate columns, pilasters, beams, cornices, or other architectural details, and thereby rendered more sightly or less noticeable.

Care should be exercised to shape the air trunks, where possible, without sharp corners and, in fact, to provide as little resistance to the passage of air as possible.

The velocity of air through the room gratings should not exceed 400 ft. per minute, and it is desirable to use an equal or less velocity for the outgoing current.

From 500 to 800 ft. per minute is the usual velocity in the flues or ducts, while that in the main duct leading directly from the fan should approach 2000 ft. per minute. In public halls or very large rooms, velocities considerably in excess of the above may be used.

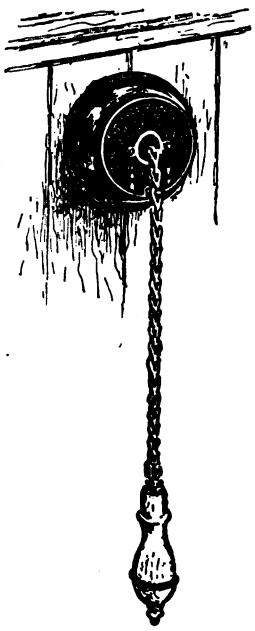

FIG. 7.—DAMPER REGULATING CHAIN.

The great advantage of such a system as that just described, is that it provides ample ventilation as well as warmth. The secondary advantages are, that windows need not be opened to provide ventilation: draughts are not experienced near badly fitting doors or windows, because all leakage of air must be outwards from the room, instead of inwards as is usual; and its action is positive and under complete control. There is also an absence of leaking steam or water, and especially of water-hammer, while no part of the apparatus is put out of order by the accumulation of air or water. There is an absence of unpleasant odour, and the perennial repairs, unpleasant alike to governors, teachers, students, and the supervisor of the plant, are practically avoided.

There appears to be hardly a branch of engineering work of which so few trustworthy data have been published as that of warming a building. Even some makers of heating appliances do not appear to be able to arrange their heating surface to maintain all rooms comfortably warm. A number of factors have to be considered—such, for example, as the aspect of a room.

Rooms with a south aspect often attain, in winter, a temperature some degrees higher than other rooms facing north or east, while the cold winds in March make the latter rooms much more difficult to warm.

Windows, and especially skylights, have a very cooling influence on a room. Again, a radiator placed within a couple of inches

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of an outer wall is constantly radiating heat into the wall, through which most of it passes to the atmosphere and is wasted. Had the radiator been situated near an inside wall, the heat would be all spent usefully.

Radiators are invariably placed immediately under windows; and therefore in that part of the room in which they are least efficient, on account of the ease with which the window permits the heat to pass into the outer air. They are placed there because the currents of hot air rising from them carry dust and soot particles: these adhere to the first surface with which they come in contact; and windows can be more easily cleaned than walls. Some makers arrange curved deflectors over their radiators, which direct the currents of hot air away from the walls into the room, and this prevents a good deal of the discolouration spoken of. The writer has removed radiators from under windows to other positions in rooms, with a very marked increase in heating efficiency.

There is another reason why a radiator should not be placed under a window. Whenever an increase in ventilation is desired, and this is frequent, the natural thing to do is to open the window at the top. The column of heated air rising from the radiator passes directly out through the open window without doing any appreciable good, except in encouraging ventilation.

Sometimes heating pipes are placed just under skylights, with the idea that they will warm the descending current of air that has been cooled by the skylight, before it reaches the heads of the occupants of the room. In the case of class rooms the air soon becomes vitiated, resulting in a desire for increased ventilation. A window and skylight, or louvre, are then opened, with the result that the overhead heating-pipe now only warms the current of air before it passes directly into the outer atmosphere.

An open window or ventilator does not produce identical effects in different parts of the same building. For instance, the corridors on different floors are often open to one another through staircases. If a window or two be open in the top corridor, causing a current of warm air to ascend the stairs and pass into the open air, an open window in the basement will be an inlet only, and sometimes a very effective one, too, with the result that the basement will be severely chilled in the neighbourhood of the open window if the temperature of the outer air is low. The same also applies to rooms, but in a less degree.

FIG. 8.—AIR INLET AND OUTLET.

The air enters the room by the upper grating over the blackboard and passes out through the lower grating. The regulating chain is shown to the right of the lower grating.

It is not generally known how quickly a room can be chilled in winter, when doors and windows are opened simultaneously; especially when there is a clear blow through for the cold air. Ten minutes of this sort of thing will often undo the work of a couple of hours of heating. The same applies to a cold week-end during which no heating has taken place.

It is almost as unpleasant to be overheated as to be very cold; and this cannot be prevented, especially in damp muggy weather, unless the occupants of a room have complete control over the amount of heat supplied. Not only should each room be independent of its neighbour, but each floor should be capable of isolation.

Different people prefer different temperatures; in fact, what one would call comfortable another would require an overcoat to endure. When a thermometer on a wood tablet resting against a wall indicates 55° F., and there is no draught, the room will be found to be fairly comfortable, the actual temperature of the air in the room being then about 57° or 58°; but a thermometer reading of at least 60° should be aimed at, while if

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the room is draughty, 65° or 70° may not be too high.

In the case of rooms used for drawing purposes, a rather higher temperature is necessary than in ordinary class rooms, as the fingers using the pencil should be entirely free from sluggishness, which often obtains in the winter though the draughtsman may not feel cold.

Proper regulation can only be attained by positive means. All levers, chains, or valves should be labelled, and directions fixed on or near the regulator. It does not follow, because a radiator has a couple of connecting pipes, that it has also positive circulation. These pipes are too often connected to the same steam-pipe, and hence the action is diffusive and not positive. What is still worse with this class of radiator is, that as a rule, a screw-down valve is supplied at one end, and either no valve at all or a non-return valve that does not work properly at the other. If the supply is shut off the steam comes in through the other connection, and this is often accompanied by banging and leakage of water on to the floor.

Radiators in which joints are made with rubber washers should never be permitted; after a time (generally from two to three years) leakage can only be prevented by taking them to pieces and renewing the washers. This is very objectionable, as the room containing the radiator must remain without heat until the repairs have been completed. This also emphasises the statement previously made, that the rooms and floors should be carefully sectionised. In this way only can repairs be carried out with the minimum of inconvenience.

It is of the utmost importance when installing a heating apparatus that all valves, joints, and practically all the pipes should be easily approached, in view of repairs, alterations, or future additions. A drawing should be retained on the premises showing clearly all the pipes and valves. This will be found most useful in locating defects, and it permits additions to be made with the minimum of expense.

It is useful and desirable in technical institutions to possess the means whereby the amount of steam and coal used may be measured. It is only in this way that the extravagance of a badly-arranged system can be adequately appreciated. Recording instruments are valuable as a check upon the attendants in charge, and a log-book should be kept. The absence of measuring appliances accounts in a great measure for the absence of reliable data respecting heating systems.

The illustrations of the Reducing Valve and Steam Trap have been kindly supplied by Messrs. Schaffer and Budenburg, and those of the Hot Air System of Heating and Ventilation by the Sturtevant Engineering Company of London.

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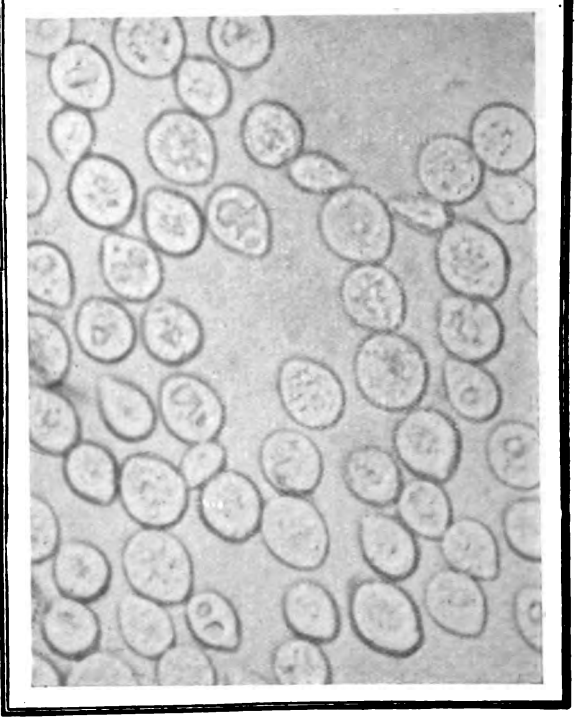
BACTERIOLOGY APPLIED TO BREWING · PART II ·

·by·
JAS. GRANT. F.I.C., F.C.S.,



YEAST CELLS, MAGNIFIED 1,100 DIAMETERS.
Some of the cells are in process of budding.
(From a photo-micrograph by Edgar Senior.)

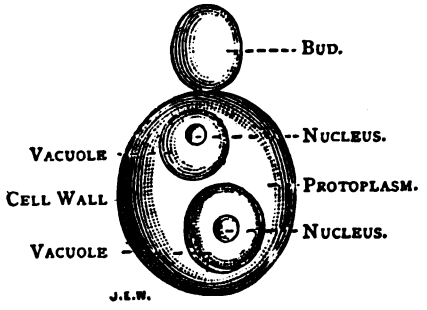
YEASTS OR MYCOMYCETES.

THESE are the botanical names given to the members of the yeast family — a group of saprophytic ferments—so named because they live on prepared foods.

Saccharomycetes (or Blastomycetes)

The saccharomycetes are divided into two classes: the ascomycetes, or true yeasts, which produce naked spores; and the second class, which embraces the remainder of the yeasts. The former are of the utmost importance in the fermentation industries, including brewing, baking, and wine and spirit manufacture.

The yeast plant consists of a single cell, round or oval in shape, averaging about 8 μ or $\frac{1}{3000}$ inch in diameter (μ = ·001 mm. = $\frac{1}{25400}$ inch). Each cell is an individual

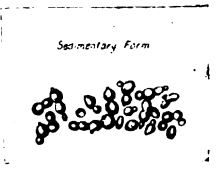


DIAGRAMMATIC REPRESENTATION OF YEAST CELL.
(By permission of Messrs. Matthews & Lott.)

plant, surrounded by a thin transparent cell-wall of cellulose, and filled internally with protoplasm or cytoplasm.

Most yeast cells develop vacuoles, and inside these a nucleus containing nuclein. The nucleus is a small round body which appears to control the activities of the cell in a way not yet fully understood. The young and vigorous cells contain a foamy and nearly transparent protoplasm, while old cells contain granular protoplasm.

If a cell-wall be ruptured by squeezing with a cover-glass or knife-blade, the protoplasm may be quite readily stained with a solution of methylene blue. Live protoplasm stainswith difficulty, but the dead substance easily takes up the colour. This reaction is frequently made use of to distinguish dead from live cells in a brewer's pitching yeast.



S. Cerevisae I.
SEDIMENTARY FORM.
(After Hansen.)

It is only quite recently that *saccharomycetes* have been discovered, which form true hyphae or mycelia; but their slender mycelia do

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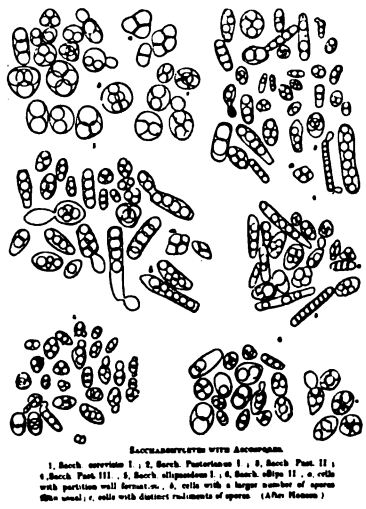
not interlace like those of moulds, hence the yeast fungi are less complex than the moulds.

Under natural conditions yeasts reproduce by gemmation or budding. The bud is primarily formed inside the parent cell, and as an enzyme or soluble ferment is formed which weakens the cell-wall, the bud is able to push its way through, after which it rapidly develops. It is divided from the parent cell by a diaphragm of cellulose, yet the bud frequently adheres, giving rise to either chain (strepto-) or cluster (staphylo-) formations.

Janssens showed that the nucleus divides previous to the division of the cytoplasm both in gemmation and sporulation.

Yeasts may also be made to reproduce by the sporulation or starvation process, by simply cultivating on a moist gypsum block, or on a slice of sterilised potato. The spores so formed possess very resisting properties, and are known as ascospores.



Saccharomyces with Ascospores.

1, Saech. cerevisiæ I.; 2, Saech. Pastorianus I.; 3, Saech. Past. II.; 4, Saech. Past. III.; 5, Saech. ellipsoideus I.; 6, Saech. ellips. II.; a, cells with partition wall formation; b, cells with a larger number of spores than usual; c, cells with distinct rudiments of spores. (After Hansen.)

Professor Dr. E. C. Hansen, of the Carlsberg Laboratories, Copenhagen, has utilised sporulation as a feature of distinction in establishing different types of yeast, account being taken both of time and temperature.

The spores vary from one to four in number in ordinary yeast, and are about 4 to 6 μ in diameter. They are set free by the dissolution of the parent cell-wall, and when brought into a sugar solution they develop and reproduce by budding. Those saccharomycetes which do not spore are not regarded as true yeasts.

There are numbers of organisms which closely resemble the yeasts, such, for instance, as the *torula*: organisms taking the forms of groups of minute, spherical, yeast-like cells, which do not usually induce beer diseases, except when present in quantity: *saccharomyces apiculatus*, a lemon-shaped yeast; *S. niger*, *S. rosaceus*, and *S. albus*—the latter three of which were discovered by Professor P. Frankland in the atmosphere—and many others; but as none of these sporulate, they cannot be regarded as true yeasts.

Pellicle of Old Culture of *S. Cerevisiae*. (After Hansen.)

Film Formation

When cultivated on the surface of a liquid at a moderately high temperature (for many yeasts 80° F. is suitable), the cells become elongated or lengthened, forming the so-called "spurious mycelia," but they never give rise to true mycelia, as is the case of certain other organisms resembling yeasts, the *mycoderma* for example, which form a characteristic film very rapidly over the surface of a wort or beer. In distinguishing one variety of yeast from others, use has been made by certain workers of the length of time and temperature required in the formation of the film.

The Chemical Composition of Yeasts

Schützenberger, in his work on this subject, showed that yeasts are composed of carbon, hydrogen, nitrogen, sulphur, water, mineral salts or ash, and perhaps traces of phosphorus.

Carbon amounts to approximately 48%.
Nitrogen varies between 9 and 12%.
Hydrogen varies between 6 and 7%.
Sulphur, about 0·6%.

Phosphorus (?) traces only in the form of lecithin. The remainder consists of water and ash. At a later period Naëgeli and Loew gave the composition of bottom yeast as—

	Approx.
Cellulose and mucilage . .	37·0 %
Albumenoids as mycoprotein	36·0 ,,
,, soluble in alcohol	9·0 ,,
Peptones precipitated by lead acetate	2·0 ,,
Fatty compounds	5·0 ,,
Extractive matters not precipitated by lead salt . .	4·0 ,,
Mineral matter.	7·0 ,,

The extractive matter consists of a peptone-like body, invertin, leucin, glucose, glycerol, succinic acid, cholesterol, guanin, xanthin, sarcin, inosite, etc.

The ratio of nitrogenous matter to cellulose is higher in yeasts than in the moulds.

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Fresh yeast capable of budding contains from 40 to 80 per cent. of water.

According to Mitscherlich, the ash of yeast varies in top fermentation and bottom fermentation.

	Top Yeast	Bottom Yeast
Potash (K_2O)	38·81 %	28·30 %
Lime (CaO)	1·08 ,,	4·20 ,,
Magnesia (MgO) . . .	6·13 ,,	8·10 ,,
Phosporic acid (P_2O_5) .	53·91 ,,	59·40 ,,

Here the proportion of phosphoric acid is much higher than in the ash of moulds.

Media

Carbon may be obtained from the sources mentioned in connection with the moulds, *e.g.*, chiefly from carbohydrates; but the solutions should be much less concentrated.

The mineral foods can be ascertained on reference to the analysis of the ash. They are mainly phosphates of potash, magnesia, and lime. There are no traces of either iron salts or chlorophyll in yeasts. The nitrogen is taken largely from organic sources, though ammonium compounds other than nitrates are available.

Nitrites act as direct poisons to yeasts, while nitrates cause a rapid deterioration, especially in the absence of free oxygen.

Generally, it may be stated that media of small concentration are necessary; ammonium salts must not exceed 1 per cent.; sugars should not go beyond 30 or 35 per cent.

Respiration

Air or free oxygen is occasionally required by yeast. Most authorities agree that a small quantity of free oxygen, and sugar solutions of about 12 per cent. strength, give a vigorous fermentation with maximum growth and multiplication of yeast cells. As the question is one of vital importance to brewers, it will be well to refer to original sources of information.

Hansen showed that, in the absence of oxygen,

(*a*) there is less growth of yeast;
(*b*) the transformation of sugar requires more time;
(*c*) the quantity transformed is greater per single cell.

Naëgeli concluded that free oxygen, although beneficial, is not absolutely necessary, provided that the media contain sugars. Oxygen is advantageous in rich sugar solutions, since it aids in the multiplication of the cells.

Pasteur demonstrated that, while the presence of oxygen is highly beneficial to the growth and multiplication of yeasts, yet those forms which are capable of breaking up sugars into alcohol and carbonic acid have the property of being able to exist in media free from oxygen; and in this case the fermentation of sugar takes place with most vigour.

During fermentation it can be observed that there are three distinct periods:—

(1) The period of rest, during which there is an absorption of oxygen and a development of the vegetative functions.

(2) A period of activity, during which the sugars are broken down or hydrolysed, and then fermented to alcohols and carbonic acid, with the production of new yeast cells in the wort.

(3) The period of slackening, in which the yeast is carried to the surface of the liquid.

Under certain conditions yeasts possess the power of abstracting oxygen from both sugars and sulphites. In the case of sulphites, sulphur bodies will be produced, and these give rise to stench; therefore, sulphites of lime and similar antiseptics can only be used with beers free from yeasts, *e.g.*, clean beers.

A trace of free acid protects the cells from many bacteria. The degree of acidity that yeast cells are capable of withstanding is much less than in the case of moulds, while few bacteria can endure any acidity at all.

Light, electricity, and high pressures appear to exert but little influence on yeasts.

Temperature

The limits of temperature for the yeasts are wide, ranging as they do from 0° to 52° C. Beyond 52° inversion of sugars may take place, but no fermentation and reproduction.

The favourable temperatures for top yeasts, as in English breweries, are between 17°-30° C. For bottom yeasts, as used in decoction breweries, the temperatures rarely exceed 13° C.

Sporulation may take place between 0·5° and 37·5° C.

Film formation is most successful for English culture yeasts about 26° to 28° C.

The Cultivation of Yeasts

If culture yeasts from a brewery are to be isolated and then grown, it should be carefully noted that towards the end of a fermentation wild yeasts, and perhaps bacteria preponderate, or, at any rate, are present in quantity; therefore the sample should be taken from the fermenting gyle about twenty-four hours from the time of pitching. A rough slide should be made, using sterile water, and examined carefully

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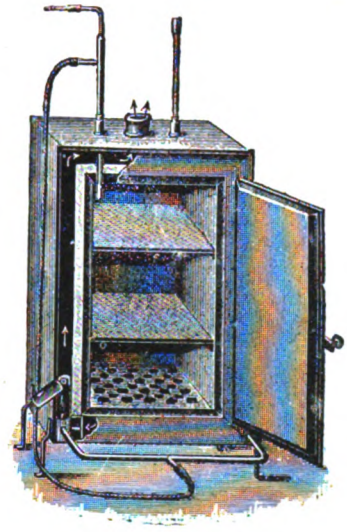
under a good microscope, so as to obtain a general idea of the condition of the yeast.

The following and some other apparatus will be necessary for the purpose :—

A sterile cultivation cupboard, Freudenreich flasks of several sizes, Petri dishes for plate cultures, Böttcher moist chambers or hollow-ground slides for droplet cultures, gypsum blocks contained in sterile Petri dishes for sporulation, two or three sizes of Pasteur flasks, hot-air or other sterilisers, thermostats for growth at fixed temperatures, a good microscope, and many sundry articles.



Hot-Air Steriliser.

Wort gelatin with a melting-point of 35° C., beer-wort, beer, 10 per cent. glucose solutions, yeast water, glucose-yeast water, etc., form suitable media for yeast culture. All the above foods must be filtered clear and sterilised. Water required for any preparations should also be quite sterile.

In the early years of this study solid media were not in use; it was only in 1872 that Schröter employed sterile slices of potato. In 1881 Professor Robert Koch used nutrient gelatin for plate cultures. By making streaks on these the number of cells gradually decreased until isolated germs were left to form colonies. In 1883 Koch modified this process by distributing the germs in liquid gelatin and pouring on to a glass plate. Neither of the methods is accurate, for Holm, of Copenhagen, found that 100 colonies yielded 108 species of germs. Still later, Kruse introduced the use of Petri dishes. These consist of two shallow glass dishes which fit one over the other. A Freudenreich flask containing wort-gelatin is infected with a few yeast cells while the gelatin is still liquid, and the contents are poured into a Petri dish. The cells form colonies which, as a rule, are fairly separated from each other and embedded in the solid gelatin.

Freudenreich Flask.

In 1893 Professor Paul Lindner introduced the droplet culture. A dilute wort culture is made, such that only a single yeast cell can be observed per drop. A drop of sterile wort is placed on a sterile cover-glass, and is infected from the diluted culture; it is then inverted on to a hollow-ground slide containing a drop or two of water. The cover-glass is cemented down with vaseline, and the preparation brought into a thermostat. On development, the colony, if single, is transferred to a Freudenreich flask, thence into Pasteur flasks, then into large glass cylinders of wort and finally into the brewery.

Professor Hansen made use of a Böttcher moist chamber for a similar object. This chamber is built up on a micro-slide by cementing on a glass ring with vaseline, introducing a few drops of sterile water, then infecting a cover-glass as before, inverting this on to the glass ring and sealing down with vaseline.

Pure Cultures by Hansen's Method

Obtain a suitable sample of strong, vigorous yeast cells. Make a slide and examine. A few cells are next introduced into a bottle of about 100 c.c. capacity, containing sterile water. The bottle and contents are shaken thoroughly for about twenty minutes, so as to dissolve gummy matters and separate the yeast cells. Withdraw a sample by means of a sterile platinum wire loop, spread evenly over the squares of a counting plate, and obtain the number of cells approximately. This may be anything between fifty and seventy. A drop of this dilution is brought into a Freudenreich flask containing sterile water, and gently shaken to distribute the cells. This dilution may give about ten cells per drop. Next, smear the under side of a cover-glass one and a half inches in diameter with "Hansen's Fluss" (this is a mixture of glycerine, alcohol and water) to keep the cells in position. Spread one drop by the platinum loop over the sticky surface, make into a Böttcher moist cell, and allow to cool. Examine under a microscope, and mark the

Petri Dishes.

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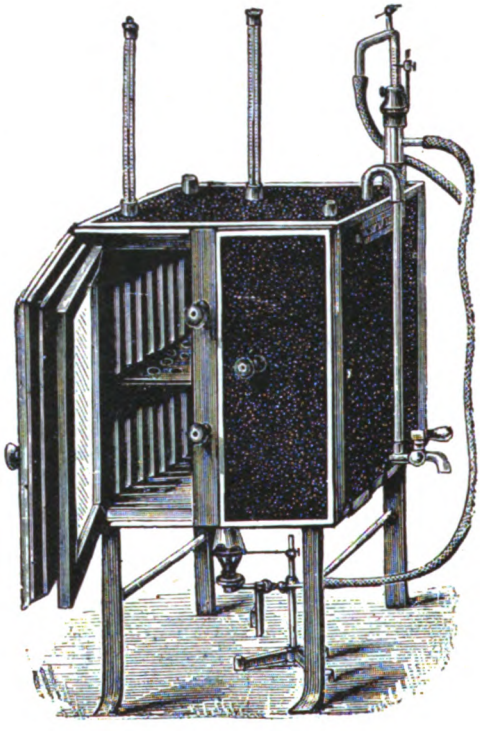
position of each yeast cell on a chart corresponding with the squares of the cover-glass. Transfer to a thermostat and maintain at 18° C. for three days. Again examine, and note that only marked cells have developed into colonies.

These marked colonies are next picked out with sterile wires about 0·5 inch long, and each wire, after being dipped into a fresh colony, is dropped into a Freudenreich flask of wort. The yeasts remain in the flasks for a few days to still further develop, one colony only being allowed in each flask.

The beer produced is partially poured off, and the remainder, together with the yeast, is transferred by sterile pipettes to Pasteur flasks of 200 c.c. capacity. The flasks are occasionally shaken during the fermentation, and in about thirty-six hours the beer is again removed and the yeast transferred into Pasteur flasks of a litre (1·76 pints) capacity. From these it passes into large cylinders of wort. Here the fermenting capacity and other factors are determined, these ultimately deciding the suitability of the yeast for brewing purposes. If everything goes well, the yeast is finally transferred to a pure yeast apparatus, from which it passes into the brewery.



THERMOSTAT.

During its cultivation from the single cell, a complete examination is made of it, viz., by plate cultures for colonies, in Freudenreich flasks on the surface of the liquid for films, by gypsum block cultures for sporulation purposes, etc. Attention is given to brilliancy of beer produced, quantity of alcohol, flavour, aroma, cloudiness, palatefulness, length of time required for fermentation, and the condition of the resulting beers.

BÖTTCHER MOIST CELL.

CLASSIFICATION.

SPECIES AND VARIETIES OF YEASTS.

Yeasts are often looked upon as being of two kinds, the culture or beer-producing yeasts, and the wild varieties. The culture yeasts are those employed in the brewing, distilling, and certain other fermentation industries for the production of beverages. They may be distinguished from the wild yeasts by the time required in sporulation, also by the large size of the spores, and by the highly refractive nature of the aqueous protoplasm of the spores.

Wild yeasts include all those which form spores, but which are not cultivated. They occur in great abundance on the skins of ripe fruits. They are carried by the wind from place to place, and thus find their way into the brewery and distillery. Their spores are small compared with those of culture yeasts, and often more highly refractive.

Yeasts may be distinguished one from another as follows:—

1. *By shape and appearance.*—The shape of a cell is dependent on (*a*) the culture medium, (*b*) the temperature of cultivation, (*c*) the age of the culture employed, (*d*) the particular culture used, (*e*) the presence or absence of air.

2. *By the differences in the mode of culture.*—Colonies of yeast in wort-gelatin are, for the first few days, almost perfect spheres; but after standing, the colonies become fringed by the development of the cells in the colony, while the cells themselves are crushed into unnatural shapes.

3. *By the differences in time and method of sporing, film-forming, etc.*

4. *By differences in fermentation and towards media.*

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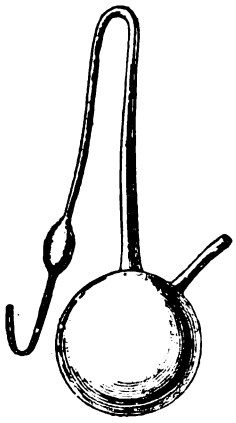
The classification of yeasts at the present time is being revised; but Hansen and Klöcker, in their new book on "Fermentation Organisms," published in 1903, recognise six species of yeasts:—

1. Those which ferment maltose, dextrose and saccharose.
2. Those which ferment dextrose and saccharose, but not maltose.
3. Those which ferment dextrose and maltose, but not saccharose.
4. Those which ferment dextrose alone.
5. Those which ferment neither of the three sugars.
6. Those which ferment lactose.



PASTEUR FLASK.

Over twenty years ago Hansen distinguished the following yeasts:—

Saccharomyces cerevisiae.
S. pastorianus I. II. III.
S. ellipsoideus I. II.

Since that time many others have become known. Ex. *S. exiguus* I. II., *S. fragilis*, which ferments milk sugar (lactose), *S. ludwigii*, *S. anomalus*, *S. membranefaciens*, etc., all of which are wild forms. Others are, *S. octosporus*, from the fact that it produces

SACCHAROMYCES APICULATUS.

A. Forms of growth; *a.* Sacch. cerevisiæ (for comparison). *B.* Stages of development of *Saccharomyces apiculatus*; *a.* 2½ hours; *b.* 3½ hours; *c.* 4 hours (all cells have taken the citron form); *d.* 5 hours (the continued development of the two cells shown on the right at *c*); *e.* 5½ hours. (After Hansen.)

A YEAST WHICH OCCURS ON RIPE FRUITS.

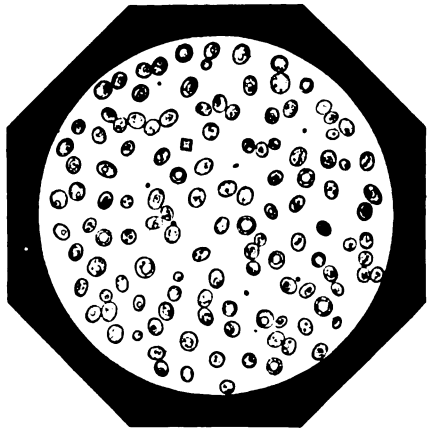
eight spores in some of its cells, *Saccharo-Schizomyces Pombé* I. II., which occurs in millet, rice and certain other beers of the tropics, and which possesses the power of fermenting some of the dextrin carbohydrates.

Saccharomyces pyriformis, a yeast similar in shape to the ellipsoideus yeasts, and which is the active ferment of ginger-beer.

Hansen and other workers have undertaken the difficult task of isolating and studying the chief characteristics of some of the wine yeasts, and up to the present have attained some success. It is important that the yeasts which confer special characteristics on wines of certain districts should be brought under the classification of culture yeasts. Of these culture yeasts a large number have been, and are being studied. All are members of the *cerevisiæ* family. Two groups are recognised—the top fermentation yeasts, as used in England and elsewhere, and the bottom fermentation yeasts.

Two interesting bottom yeasts are the *S. Carlsberg* I. II., so extensively used as pure cultures in the production of the far-famed Carlsberg lager beers.

S. cerevisiae I. is a top type of yeast, of which in England there are several well-known groups. These generally comprise larger, more globular, and more regular cells than other groups. They are very active between 14° and 25° C. During fermentation the cells are carried to the surface of the liquid, and hence entitled "top yeasts." They produce from two to four spores, each of which has a diameter of four to five microns.



ENGLISH TOP YEAST.

A strong, active, healthy yeast should possess the following characteristics:—

Uniformity of shape and size, sharpness of the cell-wall outline, presence and condition of vacuoles, nuclei not too distinct, and the absence of foreign matter.

DISEASE-PRODUCING YEASTS.

It has already been pointed out that both the *Schizomycetes* and *Hyphomycetes* play an

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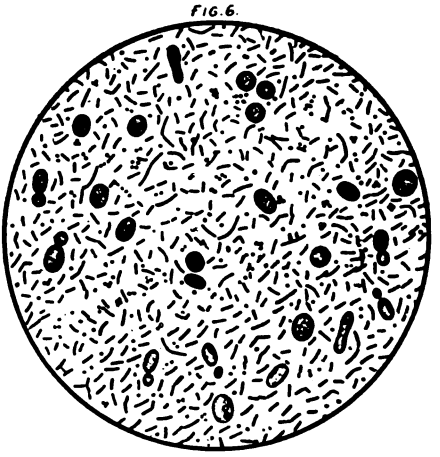
important part in brewing, some as useful, and others as disease-producing organisms. The same observation applies equally well to the yeasts.

Thus *S. pastorianus* I. gives a nauseous flavour to beers; *S. pastorianus* II. produces a bitter flavour; *S. anomalus*, a fruity flavour and cloudiness.

Some of the *Torula* give unpleasant flavours, others produce cloudiness.

Many wild yeasts, *bacteria subtilis*, and lactic and acetic organisms, are often associated together in a brewery, especially in the finished beers, much to the detriment of the latter.

FIG. 6.



IMPURE BEER DEPOSIT

THE CHIEF LITERATURE RELATING TO YEASTS.

Pasteur, Louis: Several memoirs on alcoholic fermentation.

Studies on wine, vinegar, and beer.

Hansen, Emil C.: A number of researches on the organisms of fermentation contained in the reports of the Carlsberg laboratories.

An enquiry into the practice of the fermentation industries and other works.

Jorgensen, Alfred: Micro-organisms of fermentation.

Lafar, Franz: Technical mycology, Part II.

Klöcker, Albert: Fermentation organisms.

Lindner, Paul: Atlas of fermentation organisms.

A QUICK APPROXIMATE WAY OF CALCULATING AREAS BY ACRE-SQUARES.

By F. HOWKINS.

IT is often a decided advantage to be able to estimate the acreage of an area of land on a plan drawn to a certain scale, without the expense of time and trouble necessary for an exact calculation.

For this purpose it is sufficiently accurate to rule a sheet of tracing paper or cloth with squares corresponding to acres, drawn to the same scale as the plan; by placing this tracing over the plan, a rough idea of the acreage may be readily obtained.

TABLE SHOWING ACRE-SQUARES.

Number of feet represented by 1 inch on map.	Length, in inches, of side of square representing 1 acre.
10	20·87
20	10·43
30	6·95
33	6·32
40	5·21
44	4·74
50	4·17
60	3·47
66	3·16
80	2·60
88	2·37
100	2·09

The foregoing table shows the dimensions of the squares which represent an acre on different scales.

On the 25-inch ordnance map, as is well known, a square inch is almost exactly one acre, or, to be exact, 1 acre = 1·0018 sq. in.

The foregoing table may often be used to roughly check an accurate computation, and thus ensure that no great error has been made.

It will be seen, on inspecting the table, that the length of the side of the acre-square, and the number of feet to the inch on the scale, when multiplied together, amount to about 200. Hence a very quick approximate rule to find the side of an acre-square on a plan drawn to any known scale, is to divide 200 by the scale.

For example, using a 40 scale (or 40 feet to one inch), $200 \div 40 = 5$ inches, which is the length of the side of the acre-square sufficiently close for approximation, as may be seen by referring to the above table.

This follows, of course, from the square root of 63,360 (the number of feet in an acre) being 208·71.

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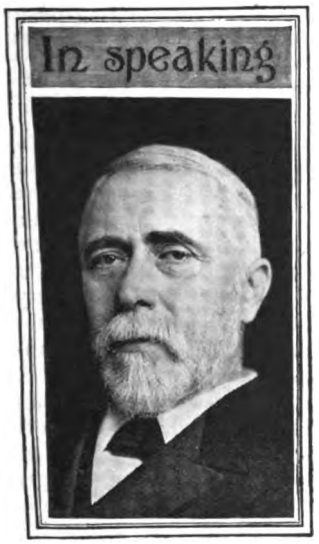
THE HIGHER TECHNICAL EDUCATION.

By SIR WILLIAM WHITE, K.C.B., F.R.S.



ON Technical Education, I think I may claim to have been in close touch with it—either in educating myself, or in educating others—during the greater part of my life. It is nearly forty years ago that, as a boy in Devonshire, I attended examinations held by the Society of Arts, which were the predecessors of the technological examinations now held by the City and Guilds Institute; and I still hold certificates which I then obtained. I treasure them as a memorial of earlier efforts which led me on to something better. I know well what it is to attend evening classes after a hard day's work, and therefore I can sympathise with those who are now following the course that I pursued many years ago; but I can say that in giving time to self-improvement, instead of to mere idleness or pleasure, young men are doing the right thing, and that when they get on in life they will feel, on looking back, that it was the best and truest course they could have pursued.

Then again, I have passed through the most thorough system of technical education which, in my judgment, exists at the present moment; and which is English from beginning to end. I know what it is to pass examination after examination: I was fortunate enough to succeed, but I always sympathise with the men who tried and did not succeed so well; and I would say to all students, do not think that the end comes with examinations. There is life beyond. Sometimes those who get the best start fail through the want of staying power and endurance; while those who fall behind at first and are slow to "get away," not unfrequently turn out winners at the end. Knowledge is worth acquiring for its own sake. One is no better for merely cramming up facts—I do not call *that* acquiring knowledge; but by assimilating information which is held ready for use, one obtains a store, priceless for future reference and guidance. The man or woman who devotes time to study, and so prepares for the work of life, is doing a noble and useful thing.

Examinations

With regard to Art, I am afraid I have no claim—no capacity; in fact, it is well known I have been looked upon and described as one of the greatest offenders against all that is artistic and beautiful. Where, I am asked, are the beautiful-looking ships of the past—the stately three-deckers and the white-winged sailing ships? What do *you* produce? Tin kettles! But if art students study the question of beauty in relation to ships, I think they will find that if the ships of old time had been deprived of sails, and left without those ornamental and graceful appendages, their reputation for beauty would have suffered. Indeed, apart from sails, modern ships do not compare badly in beauty of form with the old ones. We modern ship designers, so to speak, have our wings clipped: we cannot soar to great heights with masts and spars, or carry great sail-spreads, and so make our ships look beautiful. Stripped of their plumage, the hulls of older ships are really somewhat ugly and squat: modern ships need not fear comparison, so far as hulls are concerned; while they can claim that beauty which springs from fitness for intended service.

Art and Modern Naval Architecture

Not merely have I been a student in technical schools, but for many years I have served as a professor, so that I can sympathise with the teachers in such institutions: the men who often stand aside and see their pupils going on to greater positions and larger wealth than they themselves ever reach; while they continue their labours, animated by a noble conception of the dignity and utility of their task.

I now wish to deal with technical education in London, especially with reference to the work inaugurated by the City and Guilds of London.

It was quite natural and proper that, when systematic technical education had to be

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taken up in this country, the great and ancient Guilds of the City of London—which in their origin were formed to promote and defend the interests of trade and commerce, and to train apprentices who in their turn would become masters—it was quite natural and proper, I say, that these ancient guilds should come forward, and by their generosity and wisdom frame one of the first important schemes, which still stands in a singularly high position, now that many other schemes have been established and the whole country furnished with technical institutes and technical colleges.

Educational Work inaugurated by the City Guilds

As to the work that is being done, I gather that roughly there have been over 3,000 day students entered in the two colleges, and nearly 1,300 of these have obtained diplomas and certificates for application to their studies. Over 10,000 evening students have passed through the classes. Nearly £700,000 is provided by the Corporation and the Guilds; £23,000 is spent each year in the maintenance of this institution; over 500 day students, and a still larger number of evening students, are now being taught. Further, an important extension of the Finsbury College is about to be made. I note that in the report for last year this extension was estimated to cost £30,000, and that an anonymous donor has generously given a start to this noble effort. That anonymous donor I know well. He is a man of a thousand. A man who has made his own way, sympathises with those who want to make theirs, and finds his pleasure in using the wealth that God has given him for noble purposes.

Finsbury Technical College

I only wish that we in this country could see more of those who in the old-fashioned phrase were called "pious founders." How much do we owe to the men in the past who come under this category? We see in the United States at the present time many noble institutions of a national character established by private generosity. Shall it be said that our fellows across the Atlantic have taken from this country the old spirit, to flourish there as it did here? Recent announcements show that this is not so, and the further generosity of the City Guilds, in supplementing private offers of help to the Finsbury College, is another proof that the readiness to further worthy purposes is by no means dead.

At the present moment, as we all know, we have reached a very critical condition of affairs in relation to technical education in this country. In the January number of "Technics" I wrote of what is very dear to my heart—elementary technical education;—but what I am now referring to is higher technical education, and I say that, as a nation, we are in a most critical condition. In this connection the public is ignorant of many facts, and at present there is a tendency to go to extremes. There is a disposition towards panic; and (what is peculiarly English) there is a very marked tendency to unduly depreciate what we possess and what has been done. I should like to deal with this matter fully if space permitted, but I will simply say that we must make a new departure. This is absolutely necessary, in view of the circumstances of foreign competition, which is chiefly dangerous to us, because it springs from the advancement of technical education in other countries, and the application of trained intelligence to the conduct of foreign manufactures of all kinds. A new departure must be made: the situation must be faced; not evaded, but faced deliberately. Do not let us rush into servile methods of copying. Do not let us be ashamed to learn in any school where facts are to be learned. Basing our efforts on what we have learned, and in no small degree upon our own experience, let us endeavour, as a nation, to secure a system which shall be complete from base to summit: which shall be graduated and made into an effective and efficient whole. In this country, much has been left, and I hope always will be left, to private and local effort; but as a result, there is undoubtedly much overlapping, and in some cases there is injurious and unnecessary competition between institutions doing practically the same work in the same locality. Instances of this, of the most serious nature, have come under my own observation. Such conditions lead to waste, and worse than waste: they tend to engender feelings that should have no existence. Technical and educational institutions should work harmoniously together towards a common end, and have no unreasonable rivalry. We want, in fact, co-ordination and organisation of educational agencies on a most carefully considered and comprehensive plan. Those who teach, able as they may be, require advice from those who are conducting professional work as to the sort of information and the kind of training which will be most useful to students.

Educational Needs

Overlapping

As I have said, I am an ex-professor,

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but I venture to say, and without offence, that there is sometimes a disposition in teachers to take too much upon themselves, by claiming to regulate courses of study in technical subjects, apart from close consultation with practical men. In my opinion there should be conferences between teachers and representatives of the professions, businesses, or manufactures concerned, if the best results are to be obtained. I am happy to be able to add that in recent discussions on this subject, at the Institution of Civil Engineers and elsewhere, professors without exception have expressed the hope that such information and guidance will be given them. As a result, a special Advisory Committee is just beginning its work at the Institution of Civil Engineers. This Committee includes representatives of all the great engineering associations in this country, and its business will be to consider and report to the Council of the Institution as to the best mode of training British engineers in the future. Out of that enquiry I am hopeful that great good will come to the engineering profession. The same methods, if applied in other directions, would give equally valuable results.

Conferences Needed

Now supposing that the technical colleges were everything that could be wished, that all clashing and improper competition were done away with, there would still remain a crying need, in which, so far as I have been able to form an opinion, lies one of our greatest sources of inferiority to many foreign nations: the need of a proper system of secondary education, leading up to, and preparing students for entry into more advanced technical studies.

Secondary Education

I have never spoken to a professor in one of the technical colleges, who did not confirm the opinion that the earlier portion of the studies of most students has to be devoted to subjects that ought to have been dealt with before admission. In this matter the German system is greatly superior to our own. The Germans have taken the French system, considered it, modified it, and produced, in my judgment, a great improvement. They have a system of graduated training in secondary schools, and periodical examinations to test the standard of efficiency, which lead naturally and properly to the higher technical schools; and we must have a similar system established without delay.

Another thing we want is a decision not to persist in arguing whether the classical system of training, or the modern scientific system, is the best. Papers are full of discussions of this kind, but surely the question admits of a simple solution, viz., each system is good for certain purposes, and both should exist side by side. What is to hinder us, in this country, from doing what is general in Germany, where both modern and classical schools work side by side, on their own lines? Those who wish for a classical education go into the classical schools, and those who wish to prepare for the professions go into the modern schools. From both schools come recruits for the technical high schools, but the modern schools furnish most.

Technical and Classical Education

German common-sense system avoids the doctrine that either system is of universal application, and gives no preference to either, treating both as of the same standing in matters of appointments and social consideration. It appears to me that in this matter of the classical and modern sides there has been a great disposition in many quarters to treat the education of boys as the musical education of girls is often treated. Some unfortunate girls are compelled to hammer away on the pianoforte and to acquire some mechanical skill in execution, although they have no musical taste. So in regard to classical studies, many boys who have a capacity to use their hands for other things, will never get the chance they seek, because they are compelled to work at classical studies for which they lack inclination and capacity.

You will all remember "The Mill on the Floss," and the experience of Tom Tulliser. It is a truthful picture, but I hope the system from which it arose has received its death sentence.

The last thing I want to say is this. We must have technical education developed if this country is to maintain its position. The frank recognition of the value of training by employers, and the general employment of those who qualify in technical colleges, and who show themselves capable of doing the work, are essential conditions to our national welfare. In such matters great improvements are taking place. In my student days, in the Royal School of Naval Architecture, we had many private students of naval architecture who duly qualified and took their certificates, and wanted to go out into the world, but could find no employment. I do not think such conditions exist now. Employers partially recognise the benefits arising from the services of trained students, but I do not think

Recognition by Employers

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that British employers, as a rule, even to this day, appreciate what may be done by the free and judicious use of highly trained men. I say this advisedly, and in view of what I know is happening in the United States and Germany.

Research and Industrial Development

It is a sad thing to know that not a few researches originally made in this country have been turned to practical account abroad long before the same thing has happened here. I do not want to go into details, and will give only one illustration. A research, chiefly conducted here, was worked out to practical effect with the aid of trained students in another country, and British steel manufacturers are to this day paying large royalties in connection with the processes which were initiated here. When I recognise, as I do, that in some manufactories in this country the barest scientific staff is maintained for the conduct of the business—that there is little or no research work bearing on improvement and progress, while in other countries corresponding industries are manned by large numbers of trained men, who are encouraged to find out things new and useful—then I am forced to the conclusion that there is a great waste of power in this country, and that the sooner it is remedied the better. Employers must, in the national interest as well as in their own, be prepared to be generous to trained men; and it is a case in which the generous man will reap a rich reward.

If I have seemed urgent on this matter, please forgive me. My argument is based upon a very large and special experience. In my career at the Admiralty it was my duty not merely to design ships, but to be responsible for the manufacture and tests of materials of all sorts. Watching these things, as I have done for years, I have no fear for the future, but have every confidence in the capacity of this country to hold its own. I have the most hearty contempt for the man who thinks he is doing a great thing in showing the seamy side of our affairs to the world, as if there were no fair side. I say, without the least hesitation, that we in this country need not be afraid; and that the advertisement of our alleged inferiority in sensational articles which point to our decay in power of manufacture or invention, is unwise and should cease. It is quite right to face the facts. There is no shame in confessing that we need to change and need to improve; but to assume that this great country, which has done so much for progress in all forms of manufacture, has ceased, and necessarily ceased, to occupy—we won't say *the* leading position, but *a* leading position—is, in my opinion, suicidal.

A Technical High School for London

We are hoping to see before long the establishment of an institution in London—an institution, complete and all-embracing, which shall show how technical education ought to be conducted. Aided by the generosity of private donors, with the assistance of the authorities of the University of London, with the contributory help of all the great associations of engineers and manufacturers, and with the continued work of the City and Guilds Institute, technical education will at last be placed on a proper footing. To obtain the best results, however, we ought to have—we must have—a re-arrangement of the technical institutions of London.

One great scheme must be created which shall perpetuate what is good in our present system, remove overlapping and friction, and show the world that England is still the leader in industry and in resource.

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TECHNICS CORRESPONDENCE.

To the Editors of TECHNICS.

DEAR SIRS,—I have read with interest Mr. Drummond's article in your February number, and am genuinely pleased to see an important firm like the South Western Company endeavouring to unite the practice of their shops with the theory of the schools. I trust it will result in a race of better educated engineers, who will not in after years forget their combined *alma mater*. That "technical and practical training should go hand in hand" I certainly believe, and am on that point fully in accord with Mr. Drummond's views; but when the translation of those views into practice necessitates the attendance of teachers in the early morning, I join issue at once. Why this complete reversal of nearly 50 years of solid experience? And what are we to receive in return for such a drastic upheaval? By Mr. Drummond's own showing, the pupils are to do home work which apparently takes place in the evening; so if the evening and morning hours are both to be used on "theory," what does it matter whether the lecture occurs in the morning or the evening? As to what can or cannot be done, would it not be better to turn to those who have had the teaching to do during the last 25 years, and to ask them what their experience is?

Mr. Drummond has done a great work by uniting his practice to theory, but what a dreadful state of chaos we shall be in if one employer sends a few pupils at 8 a.m. and another has conscientious reasons against his theory being taken at any other hour than midday, while a third prefers the old evening method. Mr. Drummond has initiated another good step in permitting class-students to begin their shop work at 8 a.m. rather than at that most unearthly hour, in winter, of 6 a.m. This is all we want; we are willing that the boys should attend to their shop work during the day, if only the theory students can be permitted their full evening and before breakfast-times. From 8 a.m. to 5 p.m. is sufficient for such a youth in the workshop.

As to home work, my experience is directly contrary to that of Mr. Drummond. I find the evening students well able to do their home work, if they are treated as I have suggested; but of the few who are unable to do it at times, I regret to say that the usual excuse is "Overtime till 8·30," and such boys have been at work from 6 a.m. also.

Finally, permit me to draw attention to an article which I contributed to the *Engineering Times* in 1899, from which I quote the following which refers to shop hours:—

"Is it too much to ask that striplings of 16 to 19 might be permitted to begin at a later hour, say 8 or 9, if they can satisfactorily show that they are doing serious study every evening from 7 to 10?"

and also from the same paper the following:—

"Proposed Course of Education and Training for a young Engineer up to the age of 21:

AGE.	OCCUPATION.
Up to 13	At a primary school, with preferably some private tuition.
13 to 16	At a technical day school, studying sciences, pure and applied, and the use of tools.
16 to 19	In the mechanical workshops of a large firm, learning fitting, machining, etc.; evenings to be spent at a technical school, studying the advanced stages of applied engineering sciences.
19 to 21	In the drawing office of a mechanical, electrical, or civil engineering firm; continuing also his evening study into the highest stages of the subjects."

Such a scheme has no *sudden breaks*, and can be carried on till old age if the student chooses.

I am, sir,
Yours faithfully,
WILFRID J. LINEHAM.

[We are pleased to be able to refer our readers to the page headed "Personal Items," from which it will be seen that several firms are allowing youths who attend evening classes to commence work, in some cases at 7 a.m., and in others at 8 a.m.—ED.]

DEAR SIR,

Re Remarks in your February No. on Diagram showing Systems of Technical Education in Germany.

I notice, in your February number, a review of a diagram I used in the discussion on Mr. Wurl's paper on "Technical Education in Germany," before the North East Coast Institution of Engineers and Shipbuilders.

Your reviewer, in his explanatory remarks, has, however, fallen into a serious mistake in stating that the breadth of the diagram shows the number of youths in Germany undergoing different classes of technical education. The breadth of the diagram has no meaning whatever, and was simply drawn to a convenient scale. The purpose of the diagram was solely to show, in different vertical columns, the different systems of technical education, any one of which might be adopted by a given youth.

Trusting that the above remarks will make the matter clear,

I am,
Yours truly,
W. G. SPENCE.

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REVIEWS.

Electric Lighting and Power Distribution. An Elementary Manual of Electrical Engineering, suitable for Students preparing for the Preliminary and Ordinary Grade Examinations of the City and Guilds of London Institute. By W. Perren Maycock, M.I.E.E. Vol. II., pp. xxii. + 673. (London : Whittaker & Co., 1903.) Price 7*s.* 6*d.*

The works of Mr. Perren Maycock are deservedly popular, if only on account of their clearness of diction. The present volume is likely to be as popular amongst students as the first volume has been in the past ; indeed, though by no means above criticism, this volume is markedly in advance of its predecessor. The chief fault to be found with it is, that so many photographs are reproduced. No student could attempt to re-draw one of these illustrations in the examination room ; and since the book is confessedly written to aid students in preparing for the examinations of the City and Guilds of London Institute, this defect is a serious one. If an instance be required, the illustration of the tram-motor controller, on p. 383, may be mentioned. It can scarcely be pretended that this illustration is of any educational value, especially as a diagram showing the details of the working of the controller is not given. Also an exterior view of a Ferranti meter (p. 255) is of little use to a student ; the same remark applies to the external view of a combined choking coil and switch, on p. 139, and several other illustrations. Nevertheless the book is likely to prove useful to students, though greater stress might have been laid on numerical work. The index given is very complete, but its usefulness is diminished by the fact that numbered paragraphs, and not pages, are referred to. In such cases the numbers of the paragraphs should, at least, be printed in bold type, so as to readily catch the eye.

Testing of Electro-Magnetic Machinery and other Apparatus. By Bernard Victor Swenson, E.E., M.E., of the University of Wisconsin ; and **Budd Frankenfield,** E.E., of the Nernst Lamp Company. pp. xxix. + 420. (London : Macmillan & Co., 1904.) Price 12*s.* 6*d.* net.

This treatise embodies the course of instruction in Electrical Engineering at the University of Wisconsin. Now that so much is being said and written about technical education in the United States, it is of particular interest to have an account of the work actually being carried out at an important institution in that country.

A laboratory manual on Electrical Engineering is, further, badly needed, and the present volume is sure to be of great use to teachers and organisers. The aim of the course is to illustrate the fundamental principles of electrical engineering by laboratory tests, as nearly as possible on a commercial scale ; and at the same time to develop self-reliance and resourcefulness in the student. Success in the latter function must always depend largely on the personality of the teacher ; great care, too, must be exercised in the choice of experiments, or the student may gain his knowledge at too great a cost in damages to the machinery which he uses. Each experiment dealt with in this volume is described with great care, under the following heads :— (1) A brief review of the theory of the experiment ; (2) The particular experimental method employed ; and (3) the practical application of the knowledge gained. Ninety-six experiments, in all, are described. The calibration of electrical instruments is dealt with in sufficient detail, and most of the methods, both scientific and commercial, of testing the magnetic properties of iron, are described. Continuous current dynamos and motors form the subjects of the greater number of experiments, and these latter are well chosen, so as to induce the student to obtain as much enlightenment as possible from the experimental data he obtains. Experiments to illustrate the distinctive properties of arc-lighting dynamos, three-wire dynamos, and boosters are included. Special attention is given to "sparking" tests, and the student is also taught to locate faults in a machine. The volume closes with experiments on fuses, circuit breakers, constant pressure and constant current arc lamps, and storage cells. The illustrations are well executed and reproduced, and a useful index is appended. Advanced students will also value the copious references to original papers and books on Electrical Engineering.

The Elementary Principles of Graphic Statics. By Edward Hardy (London : B. T. Batsford, 1904). Price 3*s.* net.

The importance attaching to a competent knowledge of statics on the part of students of Building Construction and Engineering cannot be too strongly emphasised. Mr. Hardy has dealt with this subject in a simple and direct manner, which will appeal to elementary students. Some simple problems in graphic arithmetic are solved in the first chapter. The student is then introduced to the idea of force, and some of the properties of forces are deduced. It is a pity that the author has used the old-fashioned terminology of "weight" and "power" with regard to levers. One of the most important aims of education is to give students clear notions, and when the word "power" is sometimes used to denote a force, and sometimes to denote the rate of doing work, confusion can scarcely fail to result. A good feature in this book is the occasional description of experiments by which fundamental principles may be illustrated. After being presented with the most important properties of beams, the student is finally carried so far as the consideration of reciprocal diagrams. Numerical examples and their answers are given.

Books sent in too late for review in this number, will be dealt with in "Technics" for April.

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ANSWERS TO QUERIES.

STUDENTS wishing for the solutions of problems, or assistance in their scientific or technical studies, are invited to consult the Technical Editor by letter. Queries should be accompanied by the name and address of the sender, together with a *nom de plume* for publication. Queries obtained from text-books or examination papers should be accompanied by particulars of the sources from which they are derived. Queries should reach us before the 10th of the month to be answered in the next month's issue.

ENTROP.—Given the following numbers for steam, use squared paper to find dp/dt at 15° C. The latent heat of steam at 150° is 500·8 in pound-centigrade units; find the volume of a pound of steam at 150° C.

Temperature in Centigrade Degrees .	145°.	150°.	155°.
Pressure in pounds per square foot.	8,698	9,966	11,380

Board of Education, Honours (Steam), 1903.

Let p be the pressure of steam at a temperature t; and at a temperature $(t + dt)$ let the pressure be equal to $(p + dp)$. Thus the symbol dp, *taken as a whole*, represents the difference in pressure produced by a difference in temperature dt. The symbol dp/dt thus represents the rate of increase of pressure per degree rise of temperature. The pressures of steam for temperatures between 145°C. and 155°C. are plotted in the accompanying diagram (Fig. 1.) To find the value of dp/dt at 150°C., we must draw a straight line A B tangential to the curve at the point A, corresponding to a temperature of 150°C., and a pressure of 9.966. Let this line cut the 150°C. ordinate in B. From A draw the horizontal line A C, cutting the 150°C. ordinate in C. Then, if the pressure were to increase at the same rate as it is increasing at A, while the temperature rose from 150°C. to 155°C., the increase in pressure for 5° rise of temperature would be equal to C B, or 1,300 lbs. per square foot. Thus dp/dt, the increase of pressure per degree centigrade at A, is equal to 1,300 ÷ 5 = 260 lbs. per square foot per degree C.

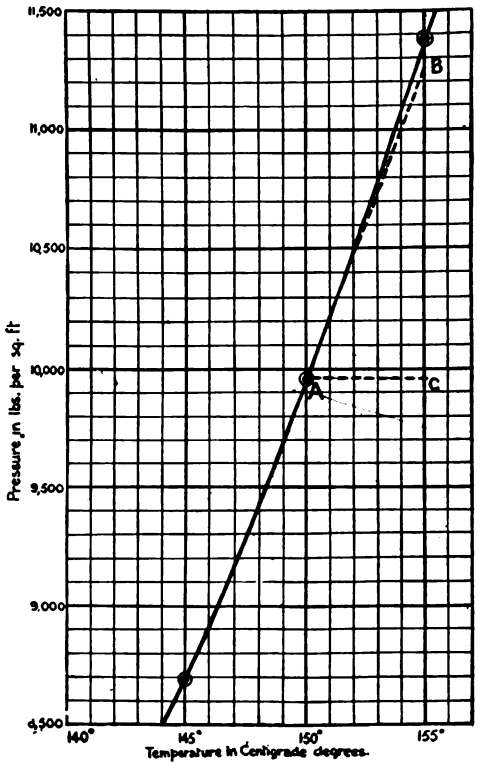

FIG. 1.

A slightly more accurate figure can be obtained directly from the figures given in the above table. As the temperature rises from 145°C. to 150°C., the pressure increases by 1,268 lbs. per square foot. As the temperature rises from 150°C. to 155°C. the pressure increases by 1,414 lbs. per square foot. Thus we may assume that, to a first approximation, the rate of increase of pressure for 5°C. in the neighbourhood of 150°, is equal to the mean of the values given above, *i.e.*, to 1,340 lbs. per square foot. Hence $dp/dt = 268$ lbs. per square foot per degree C.

The method of determining the relation between the value of dp/dt, the latent heat of steam L, and the absolute temperature T, is too long to be given here; it may be found in advanced books on Heat, as for instance in Edser's *Heat for Advanced Students*, pp. 369-371. The formula obtained is

$$\frac{dp}{dt} = \frac{L\,J}{T\,(v_2 - v_1)}$$

where J is the mechanical equivalent of heat, v_2 is the volume of unit mass of steam, and v is the volume of unit mass of water, at the absolute temperature T. We must measure J in ft.-lbs. per lb.-centigrade unit, since pressures are measured in lbs. per square foot, and volumes in cubic feet. Assuming the mechanical equivalent to be equal to 42×10^6 ergs per calorie, the value of the same quantity, in ft.-lbs. per lb.-centigrade unit, will be given by

$$J = \frac{42 \times 10^6}{981 \times 454 \times 30{\cdot}5} \times 454 = 1{,}404$$

Then

$$v_2 - v_1 = \frac{L\,J}{T} \div \frac{dp}{dt}$$

$$= \frac{500{\cdot}8 \times 1{,}404}{(273 + 150) \times 268} = 8{\cdot}121.$$

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Since 1 cubic foot of water weighs 62·3 lbs., we may take v_1, the volume of 1 lb. of water at 150°C., as equal to $\frac{1}{62\cdot5}$ c. ft. = 0·016 c. ft. Thus v_2, the volume of 1 lb. of steam at 150°, is equal to

$$8\cdot121 + 0\cdot016 = 8\cdot137 \text{ c. ft.}$$

C. J. L.—Heat is generated in a wire of 10 ohms resistance, forming part of a circuit containing a battery and having a total resistance of 25 ohms. Find the resistance of a shunt which, when applied to the extremities of the wire, will cause the heat generated in it per second to diminish in the ratio 4 : 1, assuming that the resistance of the wire does not alter sensibly with the temperature.— *Board of Education, Electricity and Magnetism*, 1903.

The rate of generation of heat is proportional to the watts dissipated in the wire. Let W be the watts dissipated, C the current in amperes, V the difference of potential in volts between the extremities of the wire, and R the resistance of the wire in ohms.

Then we have the three expressions—

$$W = CV \quad . \quad . \quad . \quad . \quad (1)$$
$$W = C^2R \quad . \quad . \quad . \quad (2)$$
$$W = \frac{V^2}{R} \quad . \quad . \quad . \quad . \quad (3)$$

The ease with which any particular problem on heat generation may be solved, depends largely on a judicious choice between the equations (1), (2) and (3). The above problem may most readily be solved by the use of (3).

Let E = the E.M.F. of the battery. The resultant E.M.F. in a circuit is numerically equal to the drop of potential all round the circuit. The portion of the total drop which occurs in any particular part of the circuit is proportional to the resistance of that part of the circuit, from Ohm's law. Thus in the original arrangement, the drop of potential, V, in the wire, is given by the equation—

$$V = \frac{E \times 10}{25}.$$

From (3) above, the watts dissipated will fall to one-quarter of the original value, if the drop of potential in the wire is halved. Therefore, we must choose a shunt of such a resistance that the potential across the shunted wire is equal to one-half of its original value. Let x be the equivalent resistance of the combination of the wire and shunt ; then, since the resistance of the remainder of the circuit is equal to (25-10) = 15 ohms, we must have

$$\frac{E \times x}{15 + x} = \frac{1}{2} \cdot \frac{E \times 10}{25} = \frac{E}{5}$$
$$\therefore 5x = 15 + x$$
$$x = 3\cdot75$$

Let R = the resistance of the shunt. Then

$$\frac{1}{x} = \frac{1}{R} + \frac{1}{10}.$$
$$\frac{1}{R} = \frac{1}{x} - \frac{1}{10} = \frac{1}{3\cdot75} - \frac{1}{10}$$
$$= \frac{6\cdot25}{37\cdot5}$$
$$\therefore R = \frac{37\cdot5}{6\cdot25} = 6 \text{ ohms.}$$

LONDON.—In a locomotive running at 60 miles per hour, a tank in the tender has a capacity of 50 cubic feet, and an average height of 6 feet above the rails. If the delivery pipe is 3½ inches in diameter, what length of horizontal reservoir is required in order to fill the tank through a scoop? Assume an efficiency of 50 per cent.— *Final B.Sc. Engineering, London University, October*, 1903.

Velocity of locomotive = v = 88 feet per second.

Sectional area of delivery pipe = a = 0·06676 square feet.

We may consider the average velocity of the water in the delivery pipe to be the resultant of two components : an upward component, equal to the velocity with which the scoop is moving through the water, *i.e.*, 88 feet per second ; and a downward component, v, due to the head of water in the pipe and tank, given by the equation—

$$v^2 = 2gh = 64 \times 6$$
$$v = 19\cdot6 \text{ feet per second.}$$

Thus the average velocity of water in the delivery pipe is equal to 88 − 19·6 = 68·4 feet per second.

Let l = the necessary length of the reservoir, assuming cent. per cent. efficiency, and let t = the time taken by the locomotive to pass over this reservoir. Then

$$l = 88t.$$

Further,

$$68\cdot4 \times 0\cdot06676 \times t = 50$$
$$\therefore l = 88t = \frac{50 \times 88}{68\cdot4 \times 0\cdot06676}$$
$$= 964 \text{ feet (nearly)}$$

With an efficiency of 50 per cent., the reservoir should be twice as long, or 2 × 964 = 1,928 ft. = 642·6 yds.

RADIO.—In the international table of Atomic Weights the substance called radium is placed among the elements with the atomic weight 225 (O = 16). How has its atomic weight been determined?

The atomic weight of radium was estimated by Madame Curie, and the method adopted consisted in determining the weight of silver chloride yielded by the most highly-purified radium chloride.

The radium chloride available weighed less than 0·1 grm., and was spectroscopically examined by M. Demarçay, who reported that it was practically free from barium, the element with which radium is accompanied up to the last stage of purification.

The numbers obtained by Madame Curie were as follows :—

Weight of Radium Chloride.	Weight of Ag. Cl.	At. Weight of Radium.
0·09192	0·08890	225·3
0·08936	0·08627	225·8
0·08839	0·08589	224·0
	Mean =	225

The atomic weight is calculated on the highly probable assumption that the element is one of

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the barium group of metals, and therefore divalent.

As radium chloride is hygroscopic, the weighings were made with a Curie aperiodic balance, which is very rapid, and is accurate to $\frac{1}{250}$ of a milligram. The hydrated chloride, obtained by crystallisation, was heated at 100° until constant in weight, when it was anhydrous, as was proved by the fact that it did not afterwards alter in weight if heated to 200°.

After every determination the excess of silver nitrate used was precipitated by pure hydrochloric acid, the silver chloride filtered off, and the solution evaporated to dryness several times with excess of pure hydrochloric acid in order to remove the nitric acid. The residual radium chloride was employed for another determination.

The precipitated chloride is always radioactive and phosphorescent, but there was no ponderable quantity of radium in it. This was proved by reducing the silver chloride by pure hydrogen, and weighing the resulting metallic silver; and also by showing that the weight of regenerated radium chloride was identical with that of the substance at the commencement of the experiment.

PHOS.—In what English scientific journal can I find the oxide of phosphorus, supposed to have the formula (P_4O) described?

Phosphorous suboxide (P_4O_1 ?) is the name given to a substance which is obtained in the following manner:—

Granulated white phosphorus is covered with a mixture of one volume of 10 per cent. caustic soda solution and two volumes of alcohol; a dark red liquid is slowly formed which, on addition of dilute acids, deposits the suboxide; or, better, 90 grams of acetic anhydride are added gradually to a solution of 30 grams of ammonium hypophosphite in 100 grams of glacial acetic acid, the product being poured into a large quantity of water.

In the latter case the substance forms a yellow, very bulky powder, having the specific gravity 1·91. It oxidises slowly on exposure to air, yielding hypophosphorous acid; in a solution of sodium hydroxide in 50 per cent. alcohol it dissolves at once without evolving any gas. (See Michaelis and Pitsch, *Berichte der Deutschen Chemischen Gesellschaft*, 1899, *32*, 337; and *Annalen der Chemie*, 1899, *310*, 45; or Chemical Society's Abstracts, 1900, ii., 137; and 1901, ii., 153.)

On the other hand, Chapman and Lidbury (*Transactions of the Chemical Society*, 1899, *75*, 973) and Burgess and Chapman (*ibid.*, 1901, *79*, 1235) maintain that the compound P_4O has no real existence, or is simply impure red phosphorus. They obtained analytical numbers for the product obtained by the usual methods, which showed that the percentage of phosphorus is invariably higher than is required for the formula P_4O, and is variable, and also that hydrogen is present in it to a considerable amount, the impurities present, therefore, being such as might be expected from the mode of preparation.

Later Michaelis and Ahrend (*Annalen der Chemie*, 1902, *325*, 361-367 *or Abstr. Chem. Soc.*, 1903, ii. 207) maintain the previous views, and assert that the analyses of Burgess and Chapman (*loc. cit.*) tell in favour of those views, the mean of their results giving 88·51 per cent. of phosphorus, whilst P_4O requires 88·57 per cent.

DIFFERENTIAL.—Prove that

$$\frac{d^2y}{dx^2} = -\frac{\frac{d^2x}{dy^2}}{\left(\frac{dx}{dy}\right)^3}$$

In the first place, it is easily proved that

$$\frac{dy}{dx} = \frac{1}{\frac{dx}{dy}}$$

This follows from the consideration that dy/dx is the tangent of the angle of slope of the curve $y = f(x)$, at the point (y, x), while dx/dy is the cotangent of the angle of slope of the curve at the same point.

Let $\frac{dy}{dx} = v$

Then

$$\frac{d^2y}{dx^2} = \frac{dv}{dx} = \frac{1}{\frac{dx}{dv}} = \frac{1}{\frac{dx}{dy}\cdot\frac{dv}{dy}} = \frac{\frac{dv}{dy}}{\frac{dx}{dy}}$$

Also $$\frac{dv}{dy} = \frac{d}{dy}\cdot\left(\frac{1}{\frac{dx}{dy}}\right) = -\frac{\frac{d^2x}{dy^2}}{\left(\frac{dx}{dy}\right)^2}$$

$$\therefore \frac{d^2y}{dx^2} = -\frac{\frac{d^2x}{dy^2}}{\left(\frac{dx}{dy}\right)^3}$$

REX.—Shew that the altitude of the greatest equilateral triangle that can be circumscribed about a given triangle is

$$\left\{a^2 + b^2 - 2ab\cos\left(\frac{\pi}{3} + C\right)\right\}^{\frac{1}{2}}.$$

—Todhunter's Diff. Calc. Max. and Min. Ex. 31.

A B C (Fig. 2) being the given triangle, let D E F be any circumscribed equilateral triangle, D, E, F being opposite to A, B C, respectively.

Let A C E = θ.

Then C A E = $\frac{2\pi}{3} - \theta$.

$$C B D = C + \theta - \frac{\pi}{3}.$$

From the triangle A E C,

$$C E = \frac{b}{\sin\frac{\pi}{3}}\sin\left(\frac{2\pi}{3} - \theta\right).$$

From the triangle D C B,

$$C D = \frac{a}{\sin\frac{\pi}{3}}\sin\left(C + \theta - \frac{\pi}{3}\right).$$

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The altitude h of D E F is given by

$$h = (\text{C E} + \text{C D}) \sin \frac{\pi}{3}$$

$$= b \sin\left(\frac{2\pi}{3} - \theta\right) + a \sin\left(\text{C} + \theta - \frac{\pi}{3}\right)$$

$$= \mathbf{A} \sin\theta + \mathbf{B} \cos\theta,$$

where $\mathbf{A} = a \cos\left(\text{C} - \frac{\pi}{3}\right) - b \cos\frac{2\pi}{3}$

and $\mathbf{B} = a \sin\left(\text{C} - \frac{\pi}{3}\right) + b \sin\frac{2\pi}{3}$.

Hence

$h = \sqrt{\mathbf{A}^2 + \mathbf{B}^2} \sin(\theta + \epsilon)$, where $\epsilon = \tan^{-1}\frac{\mathbf{B}}{\mathbf{A}}$.

The maximum value of h is $\sqrt{\mathbf{A}^2 + \mathbf{B}^2}$, or

$$\left\{a^2 + b^2 - 2ab\cos\left(\frac{\pi}{3} + \text{C}\right)\right\}^{\frac{1}{2}}.$$

The result could also be obtained by differentiating the equation—

$$h = b \sin\left(\frac{2\pi}{3} - \theta\right) + a \sin\left(\text{C} + \theta - \frac{\pi}{3}\right)$$

with regard to θ and then eliminating θ from the

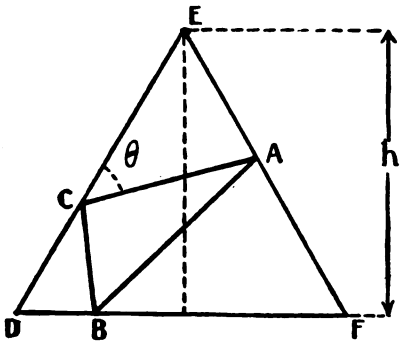

FIG. 2.

two equations; but as the elimination involves the splitting up the equation into the form

$$h = \mathbf{A} \sin\theta + \mathbf{B} \cos\theta$$

it is really simpler to use the method employed above, where differentiation is dispensed with.

ASPIRANT.—A hollow globe of glass, the internal radius of which is half the external radius, has a speck on its interior surface; prove that, as seen from a point outside the sphere on the opposite side of the centre, the speck will appear to be nearer than it is by 1/7 of the thickness of the glass ($\mu = 3/2$).—*Examination of H. M. Dockyard, Upper Division, December*, 1903.

Let u be the distance of a small object from a spherical refracting surface separating two media of which the refractive indices are in the ratio $\mu : 1$, the medium of smaller refractive index being on the positive side of the surface. Then if r is the radius of curvature of the refracting surface, the distance v of the image from that surface is given by

$$\frac{\mu}{v} - \frac{1}{u} = \frac{\mu - 1}{r}.$$

All distances are measured from the surface, and are given positive signs when the direction of measurement is opposite to that in which the incident light travels.

In the above problem let r = the internal radius of the glass globe; then the speck is at a distance $(+ 2r)$ from the surface at which refraction first occurs, so that $u = + 2r$. Then the distance v of the image, formed by the first refraction, from the surface at which the refraction occurs, is given by the equation

$$\frac{\frac{3}{2}}{v} = \frac{1}{2r} + \frac{\frac{3}{2} - 1}{r} = \frac{1}{r}$$

$$\therefore v = \tfrac{3}{2} r$$

This image is at a distance $\frac{3}{2}r + r = \frac{5}{2}r$ from the second surface; and at that surface refraction occurs from a medium of refractive index μ to one of refractive index unity. Thus, substituting $\frac{1}{\mu}$ for μ in (1), and remembering that $u = \frac{5}{2}r$, we find that the distance v_1 of the final image from the outer surface of the sphere is given by the equation

$$\frac{\frac{1}{\mu}}{v_1} - \frac{1}{\frac{5r}{2}} = \frac{\frac{1}{\mu} - 1}{2r}$$

$$\frac{1}{v_1} = \frac{2\mu}{5r} + \frac{1-\mu}{2r}$$

$$= \frac{3}{5r} - \frac{1}{4r} = \frac{7}{20r}$$

$$\therefore v_1 = \frac{20}{7} r$$

Distance of speck from outer surface on opposite side of sphere $= r + 2r = 3r = \frac{21}{7}r$.

Thus the speck appears to be nearer than it is by 1/7 of the thickness (r) of the glass.

SCIENCE.—1. In what respects is radium chemically related to barium (strontium and calcium)?

Radium can only be separated with great difficulty from barium, since the ordinary chemical properties of both substances are very similar. In both cases the sulphate is insoluble, while the chloride and bromide are soluble. The chloride and bromide of radium are less soluble in water or alcohol than the corresponding salts of barium, and this property is used to separate the two substances by fractionation. Radium has a distinct spectrum, which differs from that of barium or any other element.

2. Have the bodies polonium and actinium (or any of their compounds) been actually isolated and recognized as elements? They do not occur amongst the elements given in the International List of Atomic Weights.

Actinium is the name given to a radio-active substance discovered by Debierne, which accompanies thorium extracted from pitchblende. It possesses, in a high degree, the power of producing induced radio-activity in substances placed near it, and in this respect resembles thorium X. The latter substance can be pre-

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pared by dissolving thorium nitrate in water, and precipitating with ammonia: on evaporating the filtrate to dryness and getting rid of the ammonium salts a small residue is obtained. It was at one time thought that actinium and thorium X might be identical, but Debierne has found that actinium gives off an emanation of which the activity lasts only a few seconds, thus differing from thorium X. Actinium has not been satisfactorily isolated, nor is its atomic weight known.

Polonium is the name given by M. and Mme. Curie to a radio-active substance which they discovered; it accompanies the bismuth extracted from pitchblende, and the two substances can be separated by any of the following methods of fractionation:—

(*a*) Sublimation of the sulphides *in vacuo:* the sulphide of polonium is more volatile than the corresponding salt of bismuth.

(*b*) Precipitation of nitric acid solutions of the mixture by the addition of water: the precipitated nitrate is more active than the salt remaining in solution.

(*c*) Precipitation of an hydrochloric acid solution of the mixture by sulphuretted hydrogen: the precipitate is more active than the salt remaining in solution.

Polonium has not been obtained in a sufficiently pure state for its spectrum to be examined, or for its atomic weight to be determined. The radiations emitted by it are entirely undeviable in a magnetic field, and they apparently diminish continually as time progresses.

HYDRAULICS.—Explain the expression, "An hydraulic machine contains its own brake."—*B.Sc., Engineering, London University*, 1903.

It may be assumed that the term "brake" is used to designate an arrangement by which mechanical energy is absorbed and converted into heat. If we consider the action of a centrifugal pump, it becomes obvious that when water is delivered at the normal rate, the form given to the vanes ensures that the minimum amount of work is expended in forming eddies within the machine, nearly all of the power supplied by the prime mover being usefully employed. When, however, the pump is prevented from delivering water at the normal rate, the friction between the rotating water inside the pump and the case of the pump forms eddies, and the kinetic energy possessed by the rotating water is converted into heat. The mechanical reaction of these eddies tends to stop the motion of the vanes, or to rotate the case of the pump in a direction opposite to that in which the vanes revolve. The very efficient hydraulic brake invented by the late William Froude, consists of an arrangement of rotating vanes and stationary baffles, in which this action is brought under control. Professor Osborne Reynolds has made a further advance by admitting air at that part of the brake where the pressure is smallest: regulation of the air supply permits the brake to work with any quantity of water, from nothing to the full amount, and thus does away with the necessity of sluices. The supply of air causes the formation of eddies with air cores. The discussion of the case of a water turbine should now present no difficulties.

MAGNET.—Calculate the size, resistance, and weight of copper wire, such that if wound on a cylindrical iron core 6 inches long, 3½ inches diameter, and having a P. D. of 50 volts between its terminals, 4,400 ampere turns will be produced. The diameter of the completed coil is to be 7¾ inches. A cubic foot of copper weighs 550 lbs.—*Electric Lighting and Power Transmission, City and Guilds, Ordinary Grade*, 1900.

In the answer given to the above query in the January number of "Technics," a numerical error occurs which we are anxious to correct. The mean resistance R of a turn was proved to be equal to 0·01136 ohms; this is the resistance of a circular turn 5·625 inches in diameter, and therefore $\pi \times 5{\cdot}625$ inches in length. Taking the resistivity of copper as equal to 0·72 microhms per inch cube, the radius r of the wire is found from the equation

$$R = 0{\cdot}01136 = \frac{0{\cdot}72 \times 10^{-6} \times \pi \times 5{\cdot}625}{\pi r^2}$$

$$= \frac{0{\cdot}72 \times 10^{-6} \times 5{\cdot}625}{r^2}$$

$$\therefore r^2 = 3{\cdot}56 \times 10^{-4}$$

$$r = 1{\cdot}89 \times 10^{-2} = 0{\cdot}0189 \text{ inch.}$$

r is the radius of the bare wire. The diameter of the bare wire is equal to 0·0378 inch, and the diameter of the covered wire will be equal to

$$0{\cdot}0378 + (2 \times 0{\cdot}005) = 0{\cdot}0388 \text{ inch.}$$

Number of turns per layer

$$= \frac{6}{0{\cdot}0388} = 154{\cdot}5, \text{ or } 150 \text{ in round numbers.}$$

Number of layers

$$= \frac{2{\cdot}12}{0{\cdot}0388} = 54{\cdot}7, \text{ or (say) } 56.$$

The total number of turns, $n = 56 \times 150 = 8400$.

Total resistance of winding $= 8400 \times 0{\cdot}01136 = 95{\cdot}5$ ohms.

Volume of copper per mean turn = length of mean turn × sectional area of wire

$$= (\pi \times 5{\cdot}625) \times \pi \times 3{\cdot}56 \times 10^{-4}$$

$$= 1{\cdot}97 \times 10^{-2} \text{ c. inch.}$$

Total weight of copper

$$= \frac{1{\cdot}97 \times 10^{-2} \times 8400 \times 550}{1728} = 52{\cdot}7 \text{ lbs.}$$

CONDUCTOR. State the principles which would guide you in deciding what size of conductor to employ in a given long-distance transmission scheme, in which the P. D. and current are known. Work out the size in the case of 100 k.w. if delivered continuously through 3 miles of aerial conductor, the pressure being 2,000 volts; cost of energy = ½d. per unit, and copper erected at £150 per ton.—*City and Guilds of London, Ordinary Grade*, 1903.

In deciding the size of conductors in cases such as this, the only condition to be satisfied is that the arrangement adopted shall be as economical as possible. It is the object of a power transmission scheme to transmit a certain

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number of watts to a distant point, where they are used. During transmission losses occur due to the dissipation of energy in the conductors. These losses can be made as small as we please by giving a sufficiently large area to the conductors; on the other hand, the larger the conductors are, the more they will cost. We may assume that the money spent on conductors might have been invested so as to bring in a certain return in the form of interest, while it could be withdrawn from investment at any time if desired; thus, if the conductors were not subject to depreciation, and needed no expenditure of money on repairs, their erection would entail the annual loss of the interest on the money spent in erecting them. In addition, however, a certain percentage loss must be allowed for depreciation and repairs. The total percentage loss due to interest on capital, and to depreciation and repairs, will vary with the market value of money and of copper, and also with the cost of labour, the climate of the place where the conductors are erected, and other conditions; we may here, for simplicity, suppose that it amounts to 5 per cent. per annum on the capital outlay. Then the problem before us is *to find the condition that the annual cost of the energy dissipated in the conductors, when added to 5 per cent. per annum reckoned on the capital expended, shall be as small as possible.*

1. *Annual loss due to dissipation of energy in conductors.*

The resistivity of copper may be assumed to be equal to 0·66 microhms per inch cube. Let the radius of the conductor be equal to r inches; then, assuming that 3 miles is the length of both the mains, the resistance R of the mains, in ohms, will be given by the equation

$$R = \frac{0{\cdot}66 \times 10^{-6} \times 3 \times 1760 \times 3 \times 12}{3{\cdot}14 \times r^2} = \frac{0{\cdot}03995}{r^2}$$

Since *current* × *volts* = *watts*, the current C flowing through the mains will be given by the equation

$$C = \frac{100{,}000}{2{,}000} = 50 \text{ amperes.}$$

The watts dissipated in heating the conductors will be equal to

$$C^2R = (50)^2 \times \frac{0{\cdot}03995}{r^2} = \frac{99{\cdot}87}{r^2}$$

$$= \frac{100}{r^2} \text{ (approximately).}$$

The Board of Trade unit is equal to 1,000 watt-hours. Thus in a year the number of B.T.U.'s dissipated will be equal to

$$\frac{100}{r^2} \times \frac{365 \times 24}{1{,}000} = \frac{876}{r^2}$$

Since the cost of energy is $\frac{1}{2}$d. per unit, the cost, in pence, of the energy annually dissipated in the conductors is equal to

$$\frac{876}{r^2} \times \tfrac{1}{2} = \frac{438}{r^2}.$$

2. *Annual loss due to interest on capital, etc.*

The specific gravity of copper is equal to 8·94. A cubic foot of water weighs 62·3 lbs. Thus a cubic inch of copper will weigh

$$\frac{8{\cdot}94 \times 62{\cdot}3}{1728} = 0{\cdot}3223 \text{ lbs.}$$

The weight of the conductors will be equal to

$$0{\cdot}3223 \times (3{\cdot}14 \times r^2) \times 3 \times 1760 \times 3 \times 12$$
$$= 1{\cdot}923 \times 10^5 \times r^2 \text{ lbs.}$$

The cost of conductors being £150 per ton, the total cost in pence will be equal to

$$\frac{1{\cdot}923 \times 10^5 \times r^2 \times 150 \times 240}{2240} = 3{\cdot}091 \times 10^6 \times r^2.$$

5 per cent. of this cost is equal to

$$154{,}550r^2.$$

3. It now remains to choose r, so that

$$\frac{438}{r^2} + 154{,}550\, r^2$$

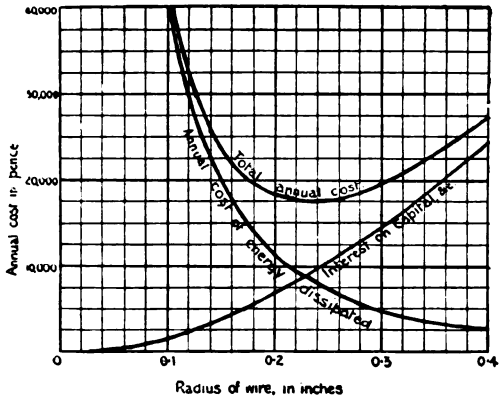

FIG. 3.

shall be as small as possible. This can be accomplished by a simple application of the Differential Calculus; but a graphical solution can be obtained, which requires no knowledge of the higher mathematics. In Fig. 3 curves are drawn showing the annual cost of the energy dissipated, and the interest per annum on the capital expended for various values of r below 0·4 inch. A number of points on each curve were found by substituting different values of r in the corresponding formula, plotting the results to a suitable scale, and then joining the points so obtained by a continuous line. A point on the curve for total cost can be obtained by adding the ordinates of the two other curves for a given value of r, and then plotting the result over that value of r. A number of points on the curve for total cost having been obtained, they were joined by a continuous line. It becomes obvious that the total annual cost is smallest when the radius of the wire is equal to 0·23 inches. This value of r is also seen to correspond with the abscissa of the point where the curves for interest and dissipation loss cross each other; thus we learn that *the most economical system will be that in which the annual cost of the energy dissipated in the conductors is equal to the interest on the capital expended, plus depreciation, etc.*

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"TECHNICS" COMPETITIONS.

A GOLD MEDAL and £200

To be awarded Annually to the "Technics" Prizeman.

£50 IN PRIZES OFFERED IN THIS ISSUE.

PARTICULARS of 27 competitions have been given in the January and February numbers of "Technics."

The present issue contains particulars of 12 competitions, for which money prizes amounting, in the aggregate, to £50 will be awarded.

At the end of the year, a prize of £200 in cash, and a Gold Medal, will be awarded to the competitor who has shown the most care, thought, and accuracy in the year's competitions.

£50 IN PRIZES.

General Rules.

Competitors are requested to note the following rules :—

All writing must be on foolscap paper. Only one side to be written upon, and a reasonable margin left.

Competitors should see that their drawings are sent either rolled or flat—flat preferred. They must not be creased. They must also be executed in black ink.

N.B.—All drawings, and each page of MS., must bear a *nom-de-plume*, and must be accompanied by a closed envelope containing the name and address of the Competitor. The outside of the envelope must bear the Competitor's *nom-de-plume* only.

The Editors reserve the right to publish, without further payment, contributions that gain prizes. Should any article or drawing that has not gained a prize be published in the magazine, payment will be made at the usual rate.

Should the best answer in any competition be deemed of insufficient merit, the Editors reserve the right to withhold the prize.

All competitions should be addressed to the Competition Department, "Technics," 3 to 7, Southampton Street, Strand, W.C., and must reach these offices not later than March 10th. Results will be published as soon as possible.

In each case the work will be submitted to an expert competent to declare which is the best practical suggestion, design, or article.

HOMEWORK PRIZES.

In May next, valuable prizes will be awarded to the students forwarding the best homework books to the Editors of "Technics." Full particulars will be published in the April number.

GENERAL COMPETITIONS.

1. The best original photographic print of a group of flowers showing the correct colour values in black and white. Competitors may choose what flowers they like, but the difficulty of correctly photographing them will be taken into account in awarding the prize. Prize £3.

2. Give a classification of dyes under the heads of the various fabrics, such as cotton, wool, silk, etc., for which they are suitable. Explain, so far as you can, the scientific principles which determine the suitability of various dyes. Prize £3.

3. Describe, with diagrams, the way in which cotton-spinning machinery utilises the properties of cotton fibres described in Mr. Dawson's article. Prize £4.

4. Describe present methods of liquefying gases, with diagrams of apparatus used. State the approximate proportion of the air pumped through the machine which is liquefied, and discuss the lines along which improvements may be expected to proceed. Prize £4.

5. A house is built in an exposed situation, and has latticed windows. Give a working drawing of the design of the windows in order to prevent rain from being forced through the crevices by the wind. Prize £4.

6. Give a description of our present knowledge of electrons, and discuss the experimental data on which this knowledge is founded. Prize £4.

7. Describe the characteristic features of a modern producer gas plant, with working drawings. Prize £4.

8. Compare the relative economies of gas (with and without mantles), electric glow lamps, Nernst lamps, and arc lamps, when used for illuminating purposes. Support your contentions with figures, and state the particular circumstances to which each form of illumination is most suitable. Prize £4.

9. The best answers to each of the four sets of questions coming under the head of Special Competitions, on page 310. Prize £5 for each set.

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SPECIAL COMPETITIONS.

QUESTIONS BEARING ON ARTICLES IN THIS NUMBER.

I.

QUESTIONS ON "THE CONTINUOUS CURRENT DYNAMO."

(1) In the illustrative example for the estimation of the full load magnetomotive force necessary for the 400 K.W. generator, for 550 terminal volts at an output of 730 amperes and at a speed of 100 r.p.m., the brushes were set with 15 segments forward lead. Make corresponding estimations for 10 segments backward lead, for neutral position and for 10, 20, and 30 segments forward lead, and show the results in a curve plotted with brush positions as abscissæ and total required magnetomotive force per field spool as ordinates. Do not discuss the matter of commutation, but consider only the magnetomotive force aspects of the case.

(2) Make corresponding calculations, but for the following conditions :—

Speed = 110 R.P.M.,

Terminal voltage = 500 volts,

Amperes output = 1000,

taking the machine just as it stands ; that is, do not re-design it for the new conditions of operation. Show clearly the steps in the calculations, and plot the final results in a curve as before.

(3) Draw a no-load saturation curve for the machine when running at 90 R.P.M. Also a saturation curve for the machine when delivering 1,000 amperes with the brushes set with 15 segments forward lead.

(4) For the conditions set forth in Question 3, draw a curve showing the variation in voltage from no load to full load of 730 amperes when supplied with a field winding adjusted to automatically compound it for 500 volts at no load, and 500 terminal volts at 730 amperes output.

II.

QUESTIONS ON PHOTOGRAPHY.

(1) Suppose it were necessary to exclude ultra-violet rays from acting upon a photographic plate, what method would you adopt?

(2) Describe and illustrate, by means of a sketch, the arrangement of apparatus for obtaining absorption spectra. What method would you adopt to indicate in a photograph the particular region or regions absorbed?

(3) Because photographic action takes place in the spectral region absorbed by the substance, would a screen of this substance, if placed in front of a light, be effective in preventing fog during development of a plate prepared with the same material?

(4) Brown stains sometimes make their appearance during the washing of prints after fixing. What are the cause of these stains? and is there any means of removing them?

III.

QUESTIONS ON CASTING.

(1) Describe the methods of casting peculiar to steel, cast iron, and brass ; explaining fully the reasons for the particular methods used in each instance.

(2) How can blow-holes in a casting be prevented?

(3) Explain the conditions in which a three-part mould must be used in casting. Give working drawings illustrating your answer.

(4) What are cores and core-prints? How must a core be made in order to secure the best possible results?

IV.

QUESTIONS OF THEORY OF STRUCTURAL DESIGN.

(1) A concentrated load of 20 tons rests on the centre of a freely supported girder of 30 ft. span. What total loads would produce the same maximum bending moment if the beam were loaded in the four following ways?—

(*a*) A uniformly distributed load, *i.e.*, for the loaded length of 30 ft., with reactions assumed at 30 ft. apart.

(*b*) A load of uniformly varying intensity ranging from zero at one end to a maximum at the other end.

(*c*) A single load of 10 ft. from one support.

(*d*) A single load of 1 ton at a distance of 2 ft. from one end, in addition to a uniformly distributed load over the whole span.

(2) Using equation 8, find the value of the constant for three plate girders selected from examples within your own personal knowledge ; or, failing this, from the calculated loads and weights given in some maker's section book. Tabulate very clearly the following particulars for the three girders selected :—

(*a*) The estimated weight as given by equation 8 when the constant is 500.

(*b*) The estimated weight as given by any other formula you can find.

(*c*) The estimated weight of the actual girder, as found by taking out the cross-sectional area, etc.

(3) Define a concentrated load, and give an example.

(4) Give definitions, with illustrative sketches where possible, of the following terms used in the theory of beams :—

Plane of symmetry ; plane of loading ; neutral axis ; neutral surface ; extreme fibres ; moment of inertia ; moment of resistance ; section modulus ; elastic line ; point of inflection.

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PERSONAL ITEMS.

OWING to the departure of Mr. James Swinburne, M.I.C.E., for South Africa, we have had to postpone the publication of the second and following instalments of the series of articles on "The Incandescent Electric Lamp," of which the first article appeared in TECHNICS for February.

SIR ARTHUR RÜCKER, M.A., D.Sc., LL.D., F.R.S., Principal of the University of London, will distribute the prizes to the students of the Woolwich Polytechnic on Tuesday, March 15th.

THE Education Committee of the County Borough of Bootle recently addressed a letter to employers, whose apprentices attend evening classes and commence work at an early hour in the morning, asking a concession of early morning time to such apprentices. In response, the following firms now allow their apprentices to attend at 7 A.M. instead of 6 A.M., on the morning following a class attendance, viz.:—

The Leyland Line.

Messrs. Fawcett, Preston & Co.

The Dublin Steam Packet Co.

Mr. T. McHugh, at whose firm the time for starting is 7 o'clock, allows such apprentices to start at a later hour.

MESSRS. BURROUGHS, WELLCOME & CO. are arranging for an historical exhibition of rare and curious objects connected with the arts of medicine and pharmacy. Mr. H. S. Wellcome, Snow Hill Buildings, E.C., will be glad to give particulars, or receive promises of exhibits.

LORD RAYLEIGH has been created a foreign Knight of the Prussian Order *Pour le Mérite* for Sciences and Arts, by the German Emperor.

MR. R. W. SINDALL, F.C.S. (wood pulp and paper trade expert), who has been delivering a course of Technical Lectures on "The Manufacture and Use of Paper," at Exeter Hall, every Friday evening since January 29th, winds up the series as under:—

March 4th—"Physical Qualities of Paper."

March 11th—"The Chemical Constituents of Paper."

March 18th—"Precautions in Warehousing Papers."

THEIR Royal Highnesses the Prince and Princess of Wales visited the Battersea Polytechnic on the 24th of February, and distributed the prizes and certificates to evening students. Amongst other distinguished visitors were Lord Londonderry (Lord President of the Council), Lord Monkswell (Chairman of the London County Council), Sir George Young (Chief Charity Commissioner), Sir Albert Rollitt (Chamber of Commerce), Sir John Wolfe Barry, F.R.S., (City and Guilds of London Institute), Sir Joseph Savory, Sir Owen Roberts, and Sir Arthur Rücker.

AT a meeting of the Students' Engineering and Metallurgical Society, University College, Sheffield, on January 29th, Mr. H. J. Davies read an interesting paper entitled "High-speed Steam Engines." The paper dealt with the advantages of high speeds for dynamo driving, and some of the most important points in the design of high-speed engines were discussed.

ON the 20th of February, a large number of the members of the Junior Institution of Engineers visited the Colonial Consignment and Distributing Company's Frozen Australasian Meat Store, Nelson's Wharf; and Hay's Wharf and Dock were open to their inspection.

A CORRESPONDENT living near Rotherham writes to say that there is no class in Organic Chemistry in Sheffield, nor within twenty miles of that city. He states that he has to travel to Leeds, a distance of thirty miles, in order to get instruction in this subject. We wish to bring this matter before the notice of the Sheffield Educational Authorities.

STUDENTS are admitted to the Physical Society of London, after applications for admission have been approved by the Council, on payment of a subscription of 10*s.* 6*d.* per annum. The membership of the Students' Section carries with it some valuable privileges. A member is allowed to attend the Science meetings of the Society, and is entitled to a free copy of the "Proceedings" and Bulletin as issued. By paying a further annual subscription of 5*s.* he receives a copy of the Physics *or* Electrical Engineering section of "Science Abstracts." By paying an annual subscription of 7*s.* 6*d.* he is entitled to *both* sections.

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RESULTS OF JANUARY COMPETITIONS.

As most of our Competitions have to be decided by experts in various branches of Science and Technology, considerable time is required for their adjudication. Many of the Competitions were very keenly contested, the general answers to the Competition on Radium being particularly good. Below will be found the results of Competitions 1, 4, 5, 8, 9, and Special Competitions I. and IV.

No. 1.—**"MY INSTITUTE."** First Prize, £5 :—

H. H. F. Hyndman, The Central Technical College, South Kensington.

Second Prize, £3 :—

R. H. Wilson, Municipal Technical School. Portadown, Ireland.

SPECIAL HONOURABLE MENTION :—

Harry Sales ; William J. Williams ; Harold Slicer.

HONOURABLE MENTION :—

V. W. Newman; Herbert John Lant; Frederic Stones ; Henry Dearden ; Albert V. Ballhatchet ; R. Light ; T. J. Monaghan, junior ; J. M. Greenway ; Harold Clarke.

No. 4. — **DESIGN FOR A PAIR OF WROUGHT-IRON GATES.** Prize £5 :—

J. E. Rawson, 176, Marlborough Street, Ashton-under-Lyne.

SPECIAL HONOURABLE MENTION :—

Frank Birch ; Frederick Rhead ; Frederick Ernest Roffey ; Charles J. Smith ; Ernest W. Pickford ; William Warwick Morriss.

HONOURABLE MENTION :—

John B. Robertson ; C. J. Mitchell ; Arthur W. Day ; Martin Shaw Briggs ; Arthur E. Sheppard ; John Webb ; H. C. Davis ; William Emmerson.

No. 5.—**DESIGN FOR CAR OF MOTOR VEHICLE.** Prize £10 :—

H. G. Lester, 44, Murdock Road, Handsworth, Birmingham.

No. 8.—**DESIGN FOR HEADPIECE.** Prize £3 :—

This prize has been equally divided between four competitors :—T. Allwork Chaplin, 32, St. Anne's Hill, Wandsworth, S.W.; Frank Bird, 20a, Chorley Old Road, Bolton, Lancs.; W. E. Barker, 19, Oakmead Road, Balham, S.W.; Alfred Oake, St. Denys, Millfield, Folkestone.

HONOURABLE MENTION.—A. Williamson ; M. A. Murray ; Walter Buchanan, junr.; Herbert G. Finchett ; Geo. M. Sullivan.

No. 9.—**DESIGN FOR TAILPIECE.** Prize £3 :—

This prize has been equally divided between four competitors :—Alan Inglis, Suir View, Clonmel, Ireland ; T. Allwork Chaplin, 32, St. Anne's Hill, Wandsworth, S.W. ; Harold Whitaker, 161, Harrow Road Extension, Leicester ; Stanley C. Rowles, 45, Santos Road, Wandsworth, S.W.

SPECIAL HONOURABLE MENTION.—E. L. Buckle, 40, Dacre Park, Lee, Kent ; H. v. Stumm, Balliol College, Oxford.

HONOURABLE MENTION.—W. H. Dry, Ethel E. Blomfield, G. H. Witham, Ellen M. Hill, S. A. Court, J. F. Bebbington, C. R. Whitehead, G. M. Sullivan, C. E. Vulliamy, T. M. Barlow, J. Appleton.

SPECIAL COMPETITIONS.

I.—**DYNAMO DESIGN.** Prize £3 :—

William J. Williams, 528, Caledonian Road, N.

SPECIAL HONOURABLE MENTION.—A. J. Aldridge.

HONOURABLE MENTION.—Wm. Neagle ; Charles Ernest Savage.

IV.—**STRUCTURAL DESIGN.** Prize £3 :—

Samuel Lees, 1, Trafalgar Street, Broughton, Manchester.

SPECIAL HONOURABLE MENTION.—W. J. Richards ; Evan Williams.

HONOURABLE MENTION.—H. Topham ; Colin S. Campbell ; A. H. Bowers.

THE APRIL NUMBER OF "TECHNICS."

AMONGST other items, the April number of "Technics" will contain several articles of exceptional interest. **PROF. H. L. CALLENDAR**, F.R.S., will contribute an article dealing with his recent researches on **PETROL MOTORS.** Prof. Callendar's previous researches on Steam Engines, carried out by the aid of the platinum thermometer, are recognised by engineers as marking one of the greatest modern advances in the theory of the steam engine.

PROF. WILFRID J. LINEHAM, M.I.C.E., will contribute an article on **MOTOR-CAR MECHANISM**, in which the latest improvements exhibited at the Crystal Palace Exhibition will be illustrated aud discussed from an engineer's point of view. Prof. Lineham's book on Mechanical Engineering is well known to all engineering students.

MR. H. M. HOBART, M.I.E.E., will continue his articles on the **CONTINUOUS CURRENT DYNAMO.** After the general considerations required in designing have been dealt with, some novel and important principles will be discussed. These relate to a rational method of determining the design suitable for a given output, voltage, and speed. The readers of Mr. Hobart's articles will thus be brought into touch with the latest phases of electrical engineering practice.

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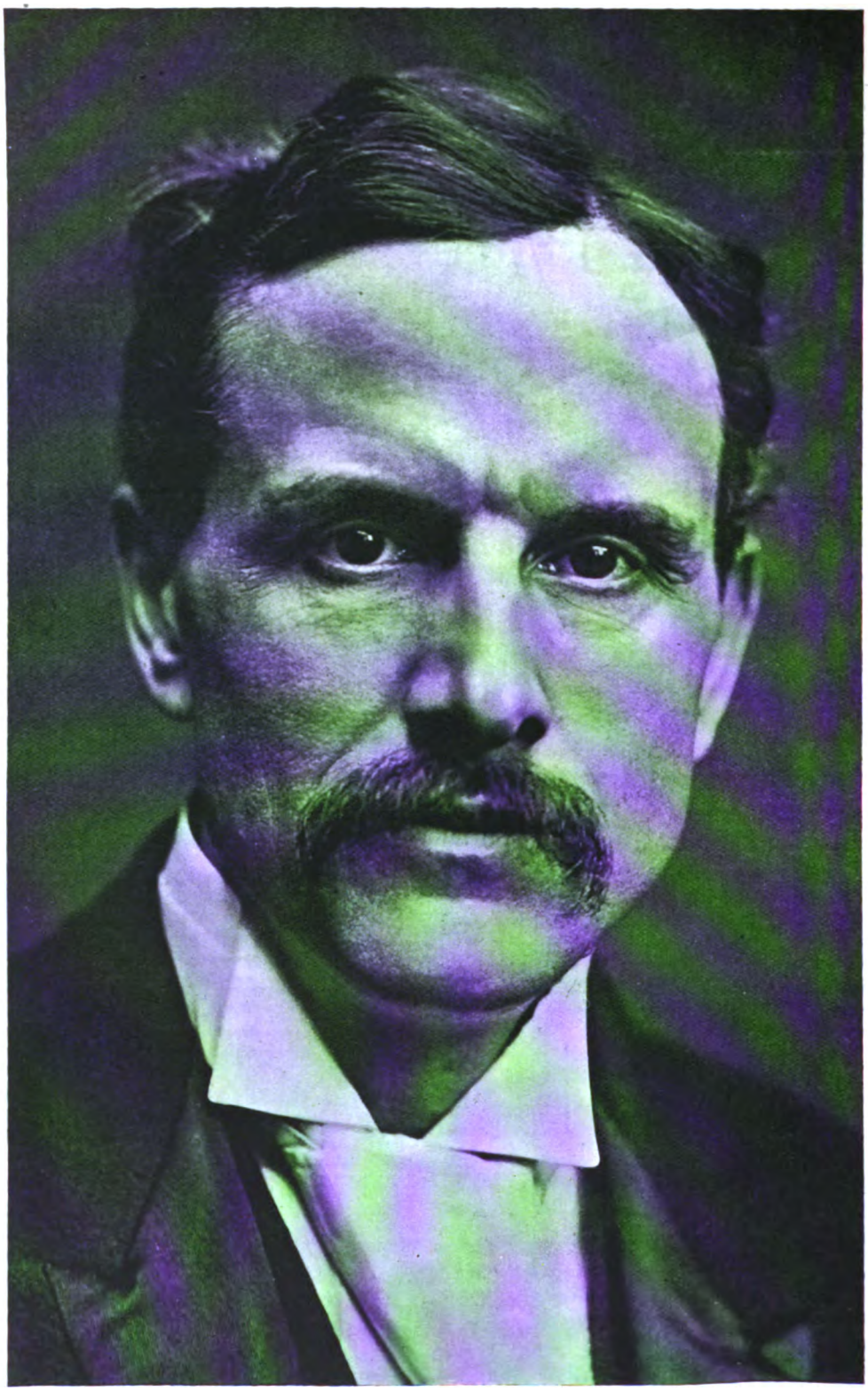

H. L. CALLENDAR, M.A., LL.D., F.R.S.

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TECHNICS

A MAGAZINE TO AID TECHNICAL PROGRESS.

VOL. I. APRIL, 1904. NO. 4.

PROGRESS OF SCIENCE AND TECHNOLOGY.

DR. DAVID WALSH has recently communicated an interesting paper to the *Medical Press and Circular*, describing cases in which radium has been successfully used to cure or modify cancers. He instances the case of a man who had undergone an operation for melano-sarcoma of the humerus, but who subsequently suffered from cutaneous nodules near the seat of the operation. The mouth of an indiarubber capsule, containing radium, was closed with a window of mica, and this was brought into contact with the skin over the nodule, the capsule being fixed with adhesive plaster. After a period varying from a quarter of an hour to twenty-five minutes, the capsule was removed. Forty-eight hours afterwards a dermatitis made its appearance. Finally the nodule disappeared, its previous position being marked by a cicatrix. Dr. Walsh also refers to the remarkable cures of rodent ulcers effected by Dr. Mackenzie Davidson, M.B.

Radium and Cancer

Radium may most conveniently be used in the form of the bromide, and should be pure. A small glass tube containing the salt may be placed in contact with the ulcerating surface. It is apparently inoperative if applied to the surface of the unbroken skin. The radium should be applied for a period between 30 and 40 minutes, which must be carefully regulated. A reaction occurs on or about the eighth day of treatment, when the temperature runs up to 100° F. in favourable circumstances; if the temperature increases to 104° F., vomiting and other distressing symptoms appear. Dr. Walsh also describes a partial cure which he has effected, of a cancer in the throat. In this case the chief difficulty lay in applying the radium, the muscles being very excitable; it was seldom that a continuous application of more than a few minutes could be made. Dr. Walsh states that the cancer has been profoundly modified, if not, as he hopes, arrested.

DAVY was the first to thoroughly investigate the discharge of electricity in air and exhausted gases. After stating that "Boyle's vacuum" is a conductor of electricity, whereas "Torricelli's vacuum" is non-conductive, he concludes that ponderable matter is necessary to the propagation of electricity. The truth of this conclusion has been confirmed by the researches of other experimenters.

The Movement of Matter in Electric Sparks

Schuster and Hemsalech, after examining the electric spark spectroscopically, and also photographing it on a rotating film, state that when the current first passes, the spark is nothing else than a "line of fire," which, on being examined through the spectroscope, shows the characteristic air bands. Subsequently the electrodes give off metallic vapours, forming a glow that surrounds the "line of fire." Under special conditions, these vapours eventually fill the space between the electrodes, when only the lines of the corresponding metal will be observed through the spectroscope. Similar differences were observed in the behaviour of the spark photograph. In fact, the "line of fire," when photographed on a moving film, is always represented by a straight line connecting the poles; whereas the image of the glow is composed of a series of strokes running away from the pole at an angle varying with the

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speed of rotation of the film. It may hence be inferred that the incandescent metallic vapour, to which the glow must be ascribed, moves with a speed of about 2 kilometers per minute.

Mr. J. Semenov (see *Journal de Physique*, February, 1904) causes electric sparks to jump between two gas flames, or a flame and a metallic electrode, or else between two metallic electrodes separated by a small gas flame. By this arrangement the glow is eliminated, so as to enable the spark proper to be examined separately. In fact, the metallic vapours constituting the glow are blown away by the gas stream of the flame. The image of the spark is projected by means of a convergent lens on the vertical slit of a direct-vision spectroscope, the axis of which is perpendicular to the plane of the spark gap.

Semenov's experiments go to show that *electric currents in gases* are characterised by *molecular movements;* this would be in accord with Professor Bouty's researches on the dielectric cohesion of gases, which is also a molecular property.

Such currents are attended by the dissociation and projection of matter in a direction perpendicular to the line of current. On account of the projection of matter taking place away from the spark, a vacuum must be produced along the spark, the atmospheric pressure throwing into this vacuum the air and metallic vapour surrounding the electrode. This is one of the causes controlling the transport of matter from one pole to the other.

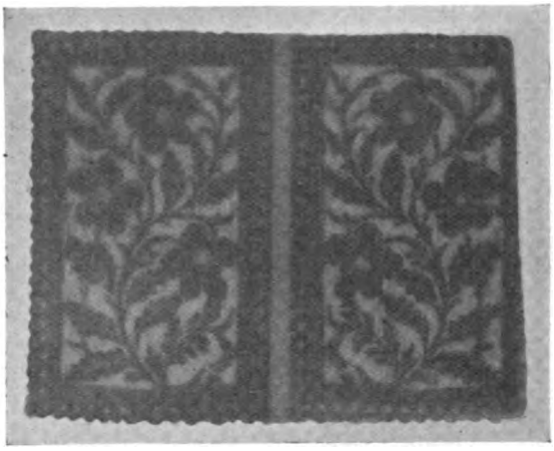

FIG. 1.—RADIUM RADIOGRAPH OF CARVED IVORY NEEDLE CASE.

THE RADIOGRAPH reproduced in Fig. 1 was obtained by Mr. Edgar Senior. An ivory needle-case was placed over a photographic plate, the latter being entirely protected from light. A small quantity of radium bromide in a closed tube was placed above the needle-case; after a suitable exposure the plate was developed, and from the negative so obtained a print was made, of which Fig. 1 is a reproduction. Curiously enough, Mr. Senior found that some impure radium bromide, which had been obtained at little expense, produced better results than a more costly sample of the pure salt. The varying opacities of different thicknesses of the ivory are very well shown in Fig. 1.

Radium Radiographs

IN A RECENT communication to the French Academy of Sciences, M. de Valbreuze records some experiments made on mercury arcs, the following phenomena being observed for pressures in the cold tube ranging between 0·004 and 0·002 mm. of mercury :—

On Some Phenomena in Connection with Mercury Arcs

On the arc being first started, the anode becomes uniformly luminous; later on it becomes covered with small stars of a high brilliancy, forming regular geometric figures. These stars are frequently located at the angles and the centre of a perfectly regular pentagon or hexagon; at other times they occur in large numbers, being of very small dimensions and moving rapidly around concentric circles. These different aspects, as a rule, alternate with one another, appearing and disappearing with extreme rapidity. As the electrode becomes hot the stars augment in size, assuming the form of spherical luminous pearls; afterwards they form groups, clinging to one another so as to form a central luminous disc, and one or more concentric luminous rings separated by dark spaces. Finally the dark spaces disappear, the anode resuming its usual aspect; namely, that of a uniformly luminous surface.

In order to account for this phenomenon, the author suggests the hypothesis of a kind of molecular membrane covering the surface of the mercury, this membrane being more or less permeable to the current, and giving rise, by its vibratory state, to the regular shapes of the figures observed.

In the second part of this communication the author deals with some peculiarities in the starting of mercury arcs. According to

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accepted views, to start vacuum tubes with one or two mercury electrodes, potential differences of some thousands of volts are required. The normal passage of the current produces a fall of potential of only about 15 volts. When applying to these tubes a potential difference of 550 volts, spontaneous starting was observed most frequently when the anode was of iron and the cathode of mercury; a previous heating is required if both the anode and cathode be of mercury. As by stirring the mercury surface, the difficulties met with in starting the arc are found to be materially diminished, the author thinks that a surface membrane, opposing (especially in the cold state) a high resistance to the passage of the current, plays a part in connection with these phenomena.

On the Conditions Controlling the Production of Electric Arcs

AT THE MEETING of November 11–24, 1903, of the Physical Section of the Russian Physico-Chemical Society, W. Mitkiewicz communicated an account of some experiments on the conditions necessary for the production of electric arcs. The author has observed the so-called Edison effect (*i.e.* that negative electric charges escape more rapidly from a heated than from a cold body), not only in a vacuum, but also in hydrogen under atmospheric pressure, between an incandescent carbon filament and a cold cylinder of the same substance. The dispersion of negative electricity proved 2,000 times stronger than the positive current in the opposite direction, the respective values being about 0·4 amp. and 0·0002 amp. per sq. cm. of the surface of the filament.

This experiment supports the hypothesis that electric arcs are due to a flux of electrons issuing from the negative electrode. The high temperature of the negative electrode of the arc is mainly due to the flux of heat from the arc. As regards the positive ions, the author thinks that they convey to the negative electrode only relatively small amounts of energy. Electric arcs can be produced between two electrodes which do not touch one another, if their ends are brought to a white heat in a stream of oxygen. If the carbon electrodes be brought to a white incandescence by the action of the arc, and the current is then interrupted, the negative electrode will spontaneously form an arc with another cold electrode; but the incandescent positive electrode does not act in this manner.

These experiments go to show the correctness of the hypothesis, according to which a high temperature of the cathode is necessary for producing and maintaining the electric arc. On this hypothesis a large number of phenomena observed in electric arcs, especially in the case of periodical extinction and re-starting, may fairly well be accounted for.

Action of Light on the Velocity of Formation of Accumulators

D. TOMMASI has observed the striking fact that the negative plate of an accumulator, when exposed to the action of light, forms more rapidly than in the case of its being left in the dark. This effect of light is observed in any case, quite independently of the composition of the active mass contained in the accumulator plate, the density of the sulphuric acid serving as electrolyte, and the working temperature. In order to further ascertain the part played by light in the formation of accumulators, Tommasi made the following experiment:—

Of two accumulators, each consisting of a glass vessel filled with acidulated water, and containing three negative and two positive plates, the one, A, was exposed to the action of sunlight, while the other, B, was placed in a pasteboard box coated with tar, and closed everywhere, so as to exclude light. The two accumulators were charged in series at from two to three amperes. In the course of the first thirty hours no appreciable difference was noted; but after this time had passed, the negative plates exposed to light were found to assume a more strongly grey coloration: whence it was inferred that they were further advanced. This difference in coloration, due to the amount of reduced lead oxide, at first increased, and then became smaller, disappearing eventually as the negative plates were wholly reduced to spongy lead.

The action of light on the *positive* plate was next investigated, by connecting together two accumulators similar to those above described, so that the two external plates were positive. One of the accumulators, A, was exposed to the action of light, while the other, B, was left in the dark. Both being connected in series, they were charged at from two to three amperes, when after about twenty hours the positive plates left in the dark showed a much darker coloration, being more strongly peroxidised than the positive plates exposed to the action of light. This experiment is held to prove that the *positive plates* of an accumulator, all else being identical, are formed *more rapidly in the dark* than in the light.

There are, in addition, permanent differences in coloration: positive plates formed in the

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dark being dark brown, while those formed in the light are reddish brown. This may be observed even after several consecutive charges; but finally, all the positive plates assume the coloration of the plates formed in the dark. The same is true of the negative plates, which, when formed in the light, are lighter in colour. The capacity of the accumulator is about the same, no matter whether they are formed in the dark or in the light.

The German High Speed Trials

THE ELECTRIC RAILWAY Studiengesellschaft, Berlin, is said to be about to resume its trial runs on the Marienfelde-Zossen military railway, though no definite time has so far been stated. The electrical equipment of the track, and especially the overhead wires conveying the current, has been left unaltered. The firms concerned are supplying the sum necessary for a continuation of the experiments. After the main object of the trials—namely, the attainment of speeds more than twice as great as present rapid train speeds—has been attained, any further trials will mostly deal with prolonged runs.

Steam locomotive high-speed trials have now been made for some time on the above line, on behalf of the railway administration. To this effect, the Prussian Railway Department has supplied both the rails required and the sum of 300,000 marks. Five different locomotives are being tested, including nearly all the types of Prussian locomotives, namely, the ordinary engine as well as superheated steam locomotives, compound and four-cylinder engines, etc., to which a sixth engine is to be added shortly. The locomotives are fitted with accurate measuring instruments similar to those used in connection with the electric railway trial runs. As the track is devoid of any devices for reversing trains, there are certain difficulties attending the experiments. There is only one small turntable in Zossen, where the locomotive may be turned, the tender being disconnected. Whenever the locomotives have to change direction at the other end of the track, they must be conveyed as far as the next large turntable of the railway department.

Nickel Steel

MUCH ATTENTION has recently been paid to the production of iron alloys containing elements other than carbon, and none of these have yielded more important results than the series in which the iron is alloyed with nickel, with or without carbon. The main advantage of nickel steel appears to consist in the fact that a metal can be obtained with very high tensile strength, but much less hard than a similar steel prepared by alloying the iron with carbon. Thus it has recently been stated by Mr. A. L. Colby that rifle barrels made from steel containing 4·50 per cent. nickel and 0·30 per cent. carbon could be cut with a penknife, although the steel had an elastic limit of over 80,000 lbs. and a tensile strength of over 100,000 lbs. per square inch. It is thus possible to machine a nickel steel of very high mechanical properties where a carbon steel could only be worked after a preliminary softening. One of the most remarkable of the alloys of nickel and iron is that containing 36 per cent. of nickel. This alloy is unique in that it has practically no co-efficient of expansion; and as its mechanical properties are satisfactory, it is being extensively used for manufacturing standards of length for surveying and other purposes, whilst an extensive field of use is open in connection with pendulums and other pieces of mechanism in which it is usually necessary to employ some mechanical device to compensate for expansion. The low co-efficient of expansion of some of the nickel steels has also led to their use in incandescent electric lamps, for sealing into the glass in place of platinum. Steel containing a considerable proportion of nickel exhibits a much smaller tendency to rust than carbon-steel, and can be advantageously used in all cases in which the metal is exposed to the corrosive action of sea-water. Boiler tubes exhibit a greatly reduced tendency to "pitting" when made from nickel steel.

Impurities

THE EXTRAORDINARY influence frequently exercised by minute quantities of foreign substances is a subject of great importance in chemical technology, and no less interesting in its bearing on chemical theory. As an instance of its bearing on manufacturing processes, it will be sufficient to mention the "poisoning," by minute traces of arsenic, and the platinum used in preparing sulphuric acid by atmospheric oxidation of sulphur dioxide; whilst Baker's recent experiments on the non-explosibility of carefully purified and dried mixtures of hydrogen and oxygen have brought to light facts which are of fundamental importance in their bearing on the theory of chemical change. A very remarkable example of the influence of impurities in accelerating and retarding chemical change has recently been studied

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by Dr. Titoff, who has examined the rate of oxidation of sodium sulphite under various conditions. Working with dissolved oxygen in order to ensure uniform conditions, it was found that the rate of oxidation could be reduced to one-hundredth of its original value by merely increasing the purity of the distilled water used in preparing the solutions. Thus the time required to oxidise half the sulphite was increased from 15 to 200 minutes by using a tinned copper still, in place of one with an iron still-head and tin condenser, to 250 minutes by using a silver still, and to 480–1,500 minutes by protecting the water from atmospheric carbon dioxide. Copper salts have a very extraordinary influence in accelerating the change, and it is stated that the velocity of oxidation is nearly doubled when a strip of bright copper is dipped into the water during less than a minute. Tin salts have a powerful effect in the opposite direction, and a solution containing 119 milligrammes of tin in 250 litres reduced the velocity of oxidation by 75 per cent.; the tin salts are, however, twenty times less active than copper salts.

An Electric Trolley Device

THE ACCOMPANYING DIAGRAM (Fig. 2) is interesting as illustrating the automatic method adopted by the London United Electric Tramways Company some few months back, for transferring the trolley from the "up" to the "down" line at their Shepherd's Bush terminus. In a crowded thoroughfare, the usual operation of changing over the trolley, by aid of a rope attached to the head, is not only to a certain extent fraught with danger, but at times—especially at night—is the cause of some delay. The arrangement represented in Fig. 2 completely does away with all such trouble, is cheap to instal, and appears to work very satisfactorily. The car approaches on the "up" line in the direction of the lower arrow, and the trolley passes over the crossing A, and along the centre path of the right- and left-handed movable point B. When it has reached the position approximately of the double arrow, the car is stopped, and the movable tongue of B is pulled by aid of the wires shown, either over to the right or left: which, does not matter. Presuming it is pulled over to the right, the car now starts backward, and its trolley, running the reverse way, is guided by the point on to the curved wire; the head of the standard of course moving through an angle to allow of this.

It reaches the Y frog C, runs over it, and as the centre of the standard arrives opposite this point, momentarily stands still at the double arrow position. The car still moves ahead, and the trolley is naturally started in the opposite direction, over C, along the other curved wire, over the crossing A, the right-hand point of the fixed three-way frog D, and so on to the "down" wire.

B is pulled over by the conductor or pointsman to whichever side is used, and held against a spring until the trolley has passed, when it is released and returns to the centre position.

To those interested in traction work or overhead construction, this apparatus is worth seeing in action, its efficiency as a time-saver being most noticeable.

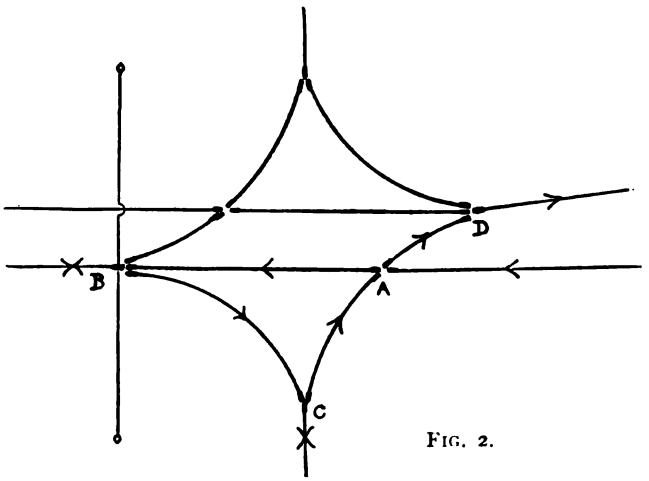

FIG. 2.

Electric Driving of Works

THE CONSERVATISM of mechanical engineers respecting the introduction of electrical driving has frequently called forth adverse criticism from the more progressive American and Continental engineer, and it is satisfactory to learn that the older methods of mechanical driving are at last fast giving place to the more flexible and economical methods of electrical driving of machine tools and works. We are told that manufacturing firms were at one time sceptical on the subject, because electrical engineers claimed too much on behalf of electrical driving; as a contrast to this view, it is refreshing to be able to give the opinion of the manager of one of our largest firms, who recently gave utterance to the following

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remarks:—"Formerly there was a feeling of unwillingness to introduce electricity, on the part of engineers, because they regarded it as a complicated subject, and thought they would have some difficulty in acquiring it, and also that there would be danger to workmen in consequence of shocks from the high voltage. The prejudices have now, to a great extent, disappeared, and *the engineer of ordinary ability finds in electricity a simple means of remedying extravagances in works more readily than by any other method, and consequently welcomes its introduction.*" In large works the introduction of a central power station removes great lengths of steam piping, which formerly was the cause of considerable loss from condensation; and in consequence, a considerable improvement in the efficiency of the plant has been effected, and by employing high-pressure boilers there has been a gain of 50 per cent. in efficiency on this score alone, compared with the old conditions with low-pressure boilers. The substitution of electricity for crane work has been one of the most useful object-lessons, whilst the use of electricity in the driving of separate machines has been the means of informing tool makers what the actual horse-power absorbed by the different classes of machines running light, or under certain conditions or loads, really was. The grouping of a small number of machines to one motor is advantageous up to a certain point, but much depends upon the class of work and the size of the machines; with grouping there is not much probability of extraordinary loads coming simultaneously on all machines; so that a smaller amount of motor power in the aggregate may be used than would be possible if the machines were driven separately, and each motor had to be powerful enough to withstand the possible overload from each machine. It is also now well recognised that in the case of large work it is more economical to bring the tool to the work than to take the work to the tool.

Organic Chemicals in Russia

THE PRODUCTION of organic chemicals in Russia has fallen far behind that in other nations, owing to the difficulty in obtaining coal tar. The attention of Russian chemists has therefore been directed to the naphtha of the country, as an alternative source, and has lately met with success. At Kureschina, 12,000 to 16,000 poods of benzol are now obtained economically, by operating on from 100,000 to 150,000 poods of crude naphtha annually.

Synthesis of Camphoric Acid

G. KOMPPA, of Helsingfors, has succeeded in synthesing camphoric acid. (*Berichte, December* 17, 1903, *f*4333).

Synthetic Aperients

AN OXYANTHRA-QUINONE derivative, diaceytl-rufigallic-tetramethylether, which has been termed "Exodin," has been proved to have strong aperient properties; it may be classed with "emodin," the "principle" obtained from rhubarb. (*Deutsch med. woch.; April* 2, 1904, 16.)

X Rays and Glandular Secretion

THE FORMATION of amylase by fresh pancreatic tissue is increased by the action of X rays, the same agency serving at first to increase, then by continued use to diminish, and even stop, glycogenesis and glycolysis in the liver and blood, according to Messrs. R. Lépine and Boulerd. (*Comp. rend.* 138, 65.)

Artificial Otto of Roses as an Adulterant

SINCE the successful production of artificial otto of roses, adulteration of the natural otto with this product has been found difficult of detection. Messrs. F. Hudson-Cox and W. H. Simmons, in a paper read before the Society of Public Analysts (March 2, 1904), explain that the iodine absorption gives a ready means of detecting this, as well as certain other adulterants. The iodine absorption of genuine otto has the range 187-194; that of the artificial product, the range 221-254 or 261-279, according as the oil does or does not contain stearopten. The iodine solution used was Hüblo's; temperature need not be considered.

Atmospheric Conditions and the Composition of Essential Oils

FROM THE RESULTS of a series of experiments, Messrs. P. Jeaucard and C. Satie have concluded that the proportion of alcohol in oil of geranium is diminished when the crops are exposed to continued cold nights, and this without an increased formation of esters; whereas in the oils of neroli and petitgrain, the proportion of esters is raised.

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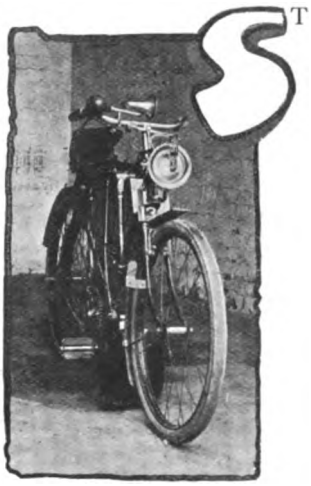
SOME EXPERIMENTS ON AN AIR-COOLED PETROL MOTOR.

By Prof. H. L. CALLENDAR, M.A., LL.D., F.R.S.



STATIONARY gas and oil engines have long been the subject of elaborate scientific investigations, which have contributed greatly to improvements in practical construction and economical working. The petrol motor, though it works on similar principles to the stationary engine, presents special features of interest, and may well claim its share of attention on account of the important part which it is destined to play in the near future. Scientific experiments on this type of engine are comparatively few; partly because it is of more recent development, and partly because, from the nature of the case, it is more difficult to test satisfactorily under the conditions of use. More particularly is this true of the small air-cooled motors so extensively used for motor cycles. These light motors are perhaps the most interesting, as being the simplest and the most powerful for their weight, and as differing most widely in construction and operation from the stationary engines which have been so carefully studied. At the same time, they are also the most difficult to test, on account of the high speed at which they run, and the rapid variations of temperature to which they are liable. The conditions affecting the distribution of temperature in such a motor are the most important and interesting to study, and afford a good illustration of the application of electrical methods of measuring temperature. In relation to the temperature question, it has also been necessary to make a careful study of the indicator diagram under various conditions of running, in order to obtain some light on the internal temperatures to which the cylinder is exposed, and to investigate the effects of load and speed, of throttling and back-pressure and retarded ignition. It would not be possible, in an article like the present, to give a full scientific discussion of all the experiments, but it is hoped that the present summary, in spite of its incompleteness, may prove interesting and suggestive as a guide to future research.

The Engine.

The engine employed in these experiments is a small Clement-Garrard cycle motor with 60 millimeters bore and 70 millimeters stroke, having a cylinder capacity of 198 cubic centimeters, or about 12 cubic inches. The clearance volume is approximately 60 cubic centimeters, or about 3/10 of the stroke. The engine has an external fly wheel and good long bearings, and is well made, so as to be capable of running at a high speed. The valves are placed on the top of the cylinder, and not in a valve-chamber at the side, which is the more usual method of construction. The position of the valves is shown in the section in Fig. 1. The advantage of having the valves on the top of the cylinder is that the heat of the exhaust is further removed from the working surface of the barrel.

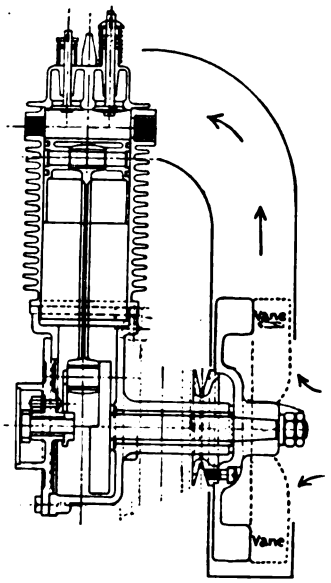


FIG. 1.—SECTIONAL ELEVATION OF ENGINE AND FAN.

The C.G. engine is much smaller than is usually fitted to a motor cycle, but is very powerful for its size. Before the commencement of the experiments, this particular engine had already driven a cycle with forecarriage attachment, the total load often exceeding five hundredweight, for a distance of nearly

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4,000 miles, at an average speed of 14 to 15 miles per hour in all kinds of weather. Engines with cylinders of double the capacity are generally used for this purpose. In spite of this heavy work, the engine has not required any replacements, and appears to run as well as ever. It was tested with the old valves, etc., in place, as nearly as possible under the ordinary conditions of running, without any special preparation, to get as fair a test as possible of the performance of an engine of this kind when in good average running order. The only alterations made in the accessories were the addition of a cooling fan, illustrated in Fig. 1, to enable the engine to run at low gears for hill climbing; and a variable speed gear for the same object. A slight modification was made in the carburettor, to make the proportions of the gas and air mixture independent of the speed; and a simple arrangement was added to enable the tension of the inlet valve spring to be adjusted while running for experimental purposes.

The engine, like most other internal combustion engines, works on the Beau de Rochas, or four-stroke cycle of operations. (1) *Suction*:—An explosive mixture of air and petrol vapour, formed in the carburettor, is sucked into the cylinder on the down stroke of the piston through the inlet valve, which closes on the completion of the down stroke. (2) *Compression*:—The mixture is compressed during the next upstroke of the piston into the clearance volume in the cylinder head. (3) *Explosion*:—The compressed mixture is ignited when the piston is near the top of its stroke, and the increase of pressure due to the explosion drives the piston forward with a much greater force than was required to compress the mixture in the compression stroke. (4) *Exhaust*:—The exhaust valve is opened near the end of the explosion stroke, and the burnt gases are expelled through a silencer during the return stroke of the piston. The exhaust valve closes at the end of the stroke, and the cycle of operations then recommences.

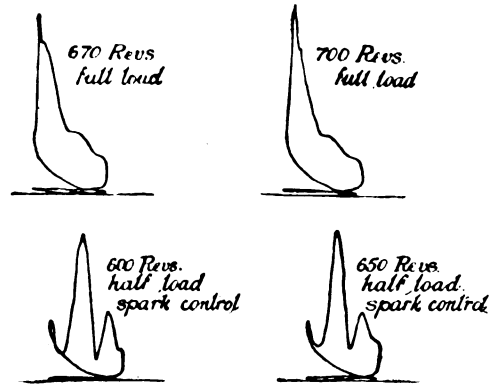

FIG. 2.—INDICATOR DIAGRAMS OF PETROL MOTOR. (CLERK.)

The Indicator or Manograph.

For the purposes of this investigation, a special type of indicator was employed in order to obtain trustworthy results at high speeds. The indicator of the ordinary type employed in steam engine or gas engine work at moderate speeds (up to, say, 500 revolutions a minute), is totally inadequate for a little motor running at 2,000 revolutions per minute. In the common type of indicator the pressure of the steam, or of the exploding gas, is allowed to act on a small piston, which is raised against a stiff spring and causes a pencil to move upwards over the surface of a sheet of paper through a height proportional to the pressure. Simultaneously the sheet of paper is moved backwards and forwards by suitable mechanism, so as to keep time with the motion of the piston in the cylinder of the engine.

This type of indicator is unsuitable for high-speed work for several reasons. If the indicator piston is adjusted, as it should be, to move with very little friction, the suddenness of the explosion sets it in a violent state of vibration, which is well shown in the accompanying diagrams (Fig. 2), taken by Clerk from an engine running at 600 revolutions per minute. The vibration is due to the inertia of the piston and pencil mechanism; and since effects of inertia generally vary as the square of the speed, it is easy to see that such an indicator would be quite useless for a speed of 2,000 revolutions. It would also be very difficult, at this speed, to devise a mechanism capable of moving the paper accurately in time with the piston. These difficulties are overcome by employing (1) an elastic steel plate or diaphragm, in place of a piston and spring, to receive the pressure, and (2) a weightless ray of light, instead of a pencil and lever, to magnify and record the movements of the diaphragm. This form of indicator was, I believe, first suggested by Professor Perry, and is made in a practical form for light motors, under the name of the Hospitalier-Carpentier Manograph. Referring to Fig. 3, which shows the essential parts of the instrument in a diagrammatic form, the pressure is transmitted from the engine through a tap T by a long flexible copper tube about

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a meter in length to the steel disc D, at the end of a box like a camera. A ray of light entering through a tube at O, in the side of the box, is reflected by a prism P on to a light pivoted mirror M, which is tilted up and down through a small angle by the movements of the steel disc. The ray of light is focussed by the mirror on a ground glass or photographic plate A B at the other end of the box, so that the pressure acting on the disc is indicated on a greatly magnified scale by the movements of the spot of light. Unfortunately, the scale of pressure is not one of equal parts, so that the diagrams cannot be measured by a planimeter. In order to make the spot of light describe the indicator diagram, and show the pressure at each point of the stroke, the mirror is simultaneously tilted from side to side by the lever L, actuated by a little crank C, which is driven by a long flexible connector from the main shaft of the engine. When the engine is running at a high speed, the spot of light is seen as a continuous curve on the ground glass, which can be projected on a screen, and made visible to a large audience by using a sufficiently powerful source of light. In this manner the action of a high-speed engine can be more effectively studied and exhibited than that of a slow-speed engine with the ordinary pencil indicator. It is very fascinating to watch the changes of the diagram with every change in the ignition, or the load, or the speed of the engine.

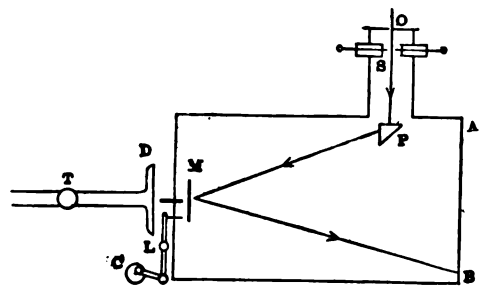

FIG. 3.—DIAGRAM OF INDICATOR OR MANOGRAPH.

Sources of Error in the Manograph.

In applying this apparatus to an engine running at so high a speed as 2,000 revolutions, it was found necessary to make some modifications to secure accurate results. The long flexible tube for transmitting the pressure, and the long flexible connector for transmitting the motion of the shaft, were evidently intended to facilitate the connection of the apparatus to any kind of engine in any position; but they obviously introduce several sources of error, especially at high speeds. The propagation of the explosion pressure through the fine copper tube takes a very appreciable time, so that the maximum pressure on the disc is much later than the maximum pressure in the cylinder. This retardation may amount to half a stroke or more at high speeds, and would very seriously distort the diagram. To get over this difficulty the makers provide an ingenious arrangement so that the position of the spot of light may be retarded relative to that of the piston by an amount equal to the retardation of the pressure at any given speed. Unfortunately, the retardation required varies with every variation in the speed of the engine, and the adjustment interferes with the accurate reproduction of the motion of the piston, for which it is necessary that the small crank C actuating the mirror should be at the top of its stroke at the same time as the crank of the engine. Again, the pressure transmitted through the long fine tube is not the same as that in the cylinder. In some cases I have found it as much as 25 per cent. less. The long flexible connector from the main shaft may also introduce variable and uncertain errors owing to its flexibility, and to torsional vibrations. These different effects combined may produce all sorts of curious errors and imperfections in the diagram, even at moderate speeds, such as 900 revolutions; and at high speeds the indications become quite untrustworthy.

In order to minimise these sources of error, the long copper tube was replaced by a short steel tube of less than one-tenth its length, and of more than three times its sectional area. The retardation was thus rendered inappreciable, and the pressures indicated were the true pressures existing in the cylinder. The flexible connector was replaced by a pair of short steel rods engaging through a bevel gear, so that the motion of the piston was accurately reproduced. With these slight modifications the instrument was found to work quite satisfactorily at speeds of 2,500 revolutions per minute or more.

Sample Diagrams.

The first pair of diagrams, illustrated in Fig. 4, were taken with a thin steel disc (giving an open scale of pressures) to measure the compression and suction pressures with different adjustments of the tension of the spring of the automatic inlet valve. For these tests the engine was driven by an electric motor. In the top diagram, with the inlet spring

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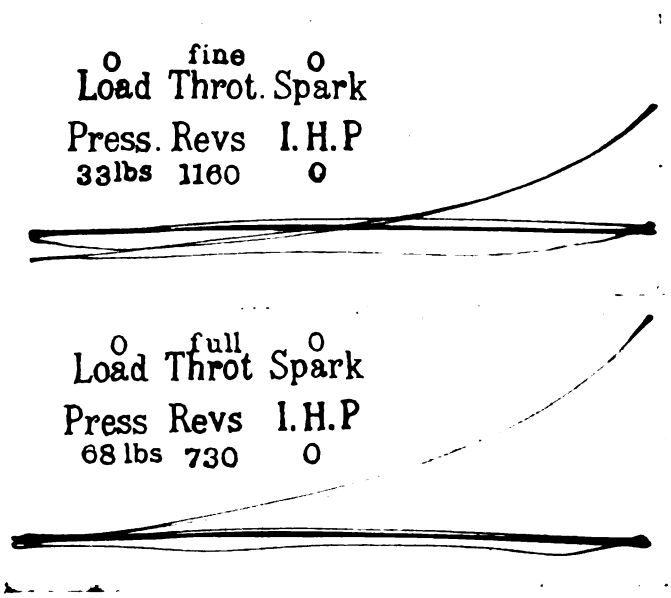

FIG. 4.—INDICATOR DIAGRAMS—COMPRESSION AND SUCTION.

at its maximum tension, and the opening of the valve limited to about one millimeter, the suction pressure is seen to be about half an atmosphere (7 to 8 lbs. per square inch) at the end of the suction stroke. The pressure does not rise to the atmospheric line (the dark thick line across the lower part of the diagram) until the piston is half-way back along the compression stroke. The compression pressure is only 33 lbs. per square inch above atmospheric. The expansion line is practically coincident with the compression line, the current being switched off so that there is no explosion. Near the end of the expansion stroke the exhaust valve opens, and the pressure returns to the atmospheric line. During the exhaust stroke the pressure rises slightly above the atmospheric. If the compression pressure is reduced, by throttling, much below the limit indicated by this diagram, the engine will not fire regularly every time, as nearly half the cylinder contents consist of burnt gases from the previous stroke. The second diagram in the same figure shows the compression and suction with a weak inlet spring. The negative pressure of suction is only 3 to 4 pounds, a nearly full charge is drawn in, and the compression pressure is more than doubled, reaching 68 pounds. Under these conditions the mixture is much stronger, being less diluted with burnt gases, and the explosion pressure is increased in a greater ratio than the compression. The temperature of the explosion is also much higher, and the cylinder would overheat rapidly if not artificially cooled. The makers generally fit a much stronger inlet spring for various reasons: partly perhaps to prevent tyros overheating their engines at full throttle, partly to diminish the risk of the cottar falling out or hammering through the slot in the stem, partly to make the inlet valve close as quickly as possible at high speeds and prevent loss of charge, and partly to secure a sudden and violent suction at the carburettor jet, which gives a finer spray and a more intimate mixture.

The two next diagrams (Fig. 5) show the

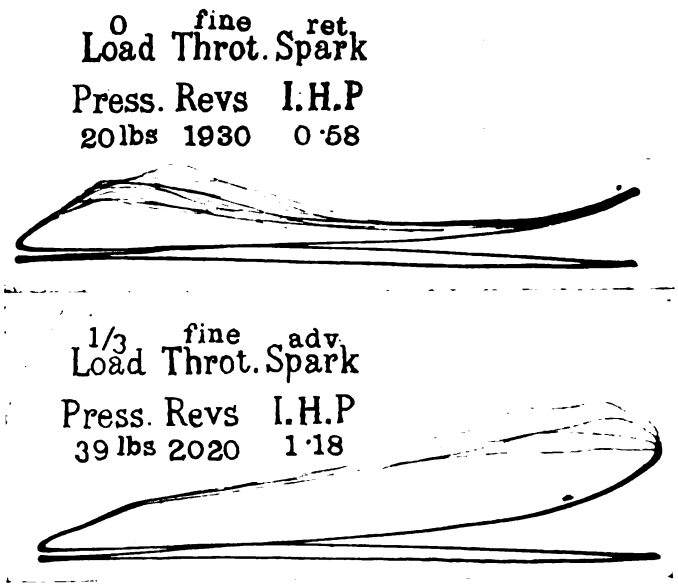

FIG. 5.—LIGHT LOAD DIAGRAMS.

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engine running at a high speed, with no load and with one-third load on the brake. The area of the no load diagram is a measure of the work required to drive the engine and gear against friction, suction, and back pressure. In this diagram the engine was running fast, but with spark fully retarded. The lower diagram shows the engine running at one-third load on the same throttle with spark advanced. The exact point of the stroke at which the spark occurs cannot be determined from the setting of the spark lever by turning the engine slowly, because there is always some retardation of the spark at high speeds, due to loss of time in the mechanism. In order to determine the exact point, a spark gap was arranged at S, close to the light aperture O in Fig. 3; and a spark, produced by the same discharge as the spark in the cylinder, was made to photograph itself on the plate. This device of photographing the spark on the indicator diagram itself makes it possible to study the phenomena of ignition accurately under the actual conditions which occur in practice. The ignition of the charge is so slow with a weak mixture when rapidly expanding, as in the no load diagram, that the maximum pressure is not reached till nearly the end of the stroke, although the spark itself takes place shortly after the beginning of the stroke. By advancing the spark so that it occurs before the end of the compression stroke, the explosion has time to develop while the piston is passing the dead centre, and the ignition proceeds more rapidly in the hot compressed gas, so that the latent period is considerably shortened.

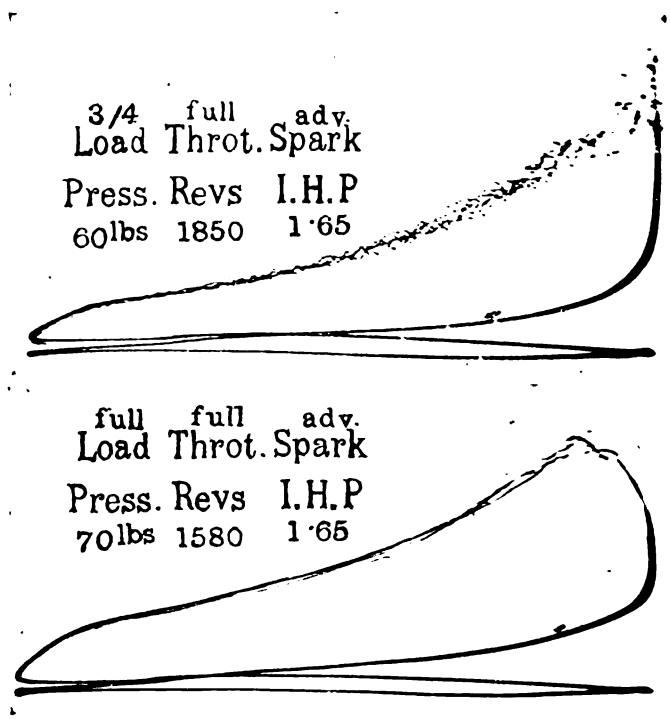

FIG. 6.—HEAVY LOAD DIAGRAMS.

The next figure (6) shows the engine running under higher loads, with 30 and 45 lbs. respectively on a brake applied to the back wheel. The first of the two diagrams shows the effect of too much spark advance. Ignition has already commenced before the end of the compression stroke. The explosion pressures are high and irregular, and the steel disc of the indicator is thrown into a violent state of oscillation, which is very pretty to watch on the ground glass, but does not reproduce very well in the photograph. In this case so much heat is lost to the walls of the cylinder before expansion begins, that the expansion pressures are reduced and the area of the diagram diminished. The second diagram, which was taken immediately afterwards, with the same setting of the throttle, etc., but with less spark advance and a heavier load, shows much higher expansion pressures and a larger area. It is evident that more work can be obtained in a small cylinder by adjusting the spark advance so that the maximum pressure is reached shortly after the beginning of the expansion stroke. The elongated dots above the compression line are the photographic impressions of the sparks in both cases. Although the mean pressure is greater in the second case, the maximum pressure and temperature are less, so that less strain is put on the engine, and less heat is wasted in heating the walls of the cylinder. The indicated horse-power happens to be nearly the same in the two cases, because the large increase of load in the second case caused a reduction in the speed, as the tension of the inlet spring was too great to admit a full supply of gas, although the throttle was full open.

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Temperature Measurements.

The most important condition affecting the efficiency of the air-cooled motor is the temperature of the cylinder, the investigation of which, under conditions of running, was one of the main objects of these experiments. It is well known that if a motor of this kind is run on the stand at full throttle for a few minutes, either with the spark fully retarded or with a load on the brake, the exhaust valve and tube and the adjacent parts of the cylinder head quickly become red-hot. This does not necessarily stop the engine until some part of the barrel of the cylinder becomes so hot that the lubricating oil is vaporized, which causes leakage of gas and greatly increased friction. The rate at which heat is communicated to any part of the cylinder evidently depends (1) on conduction of heat from neighbouring portions; (2) on the temperature of the gases to which it is exposed; (3) on the duration of the exposure; and (4) on the rate of motion of the gases over the surface. The last cause is usually the most effective, as the conducting power of a gas is low, so that comparatively little heat would be communicated by a quiescent layer of gas. The temperature actually reached by any part of the cylinder will depend obviously on the rate at which the heat is carried off by external cooling or conduction. Each part will reach a stationary temperature when the heat communicated to it by conduction and by the hot gases is equal to the heat carried off in the same time by conduction and by external cooling. To secure the most efficient action it is evident that the cooling should be arranged to keep the working surfaces of the cylinder as nearly as possible at a uniform temperature throughout. If any part becomes too hot, there will be failure of power and unequal wear. The observation of such differences of temperature as occur in the working of the engine, is the surest guide to appropriate methods of cooling.

Thermo-electric Methods.

It would not be at all an easy matter to measure the temperature at any point of the cylinder by means of an ordinary mercury thermometer, even if an instrument reading to 500° C. could be employed. The bulb might be fitted in a copper block wedged between the cylinder ribs, and protected on the outside with asbestos; but it would be slow in following the temperature of the metal, it would be difficult to read, and liable to large and uncertain errors from stem exposure and conduction. The simplest and best method is to use a "thermo-couple" (or junction of two different metals) which produces an electric current depending on the temperature of the metals at their junction or point of contact, and practically independent of the temperature of other parts of the wires. The thermo-couples employed in this investigation were pairs of wires of iron and nickel, about one millimeter in diameter. The pair of wires forming each couple were firmly screwed, side by side, into small holes in the cylinder, so as to get good electric and thermal contact. Eight couples were employed in different positions, the other ends being connected to mercury cups, so that any desired couple could be quickly connected to a galvanometer or millivoltmeter for measuring the thermo-electric force. A sensitive galvanometer with a resistance of 400 ohms was generally employed in the laboratory in connection with the indicator diagrams, to avoid small errors from variation of resistance of the wires. The millivoltmeter, being portable and giving fairly steady readings when the bicycle was in motion, was employed for obtaining temperatures under the actual conditions of running the machine on the road. Since the readings of a thermo-couple are not, as a rule, by any means proportional to the true temperature, a preliminary series of experiments was made with one of the couples to compare its readings with those of a standard platinum thermometer. It was found that the thermo-electric power of the couple fell to less than half its initial value between 300° and 400° C., but increased again at higher temperatures. It was intended at one time to use a standard platinum thermo-couple with the wires gold-soldered into a single small screw; but these couples give a much smaller thermo-electric power at low temperatures, and were not so suitable for use with the millivoltmeter, besides being more difficult to fix.

Inlet and Exhaust Temperatures.

The temperatures of the cylinder head above the inlet and exhaust valves were measured by a pair of couples screwed into the metal just over the valves. Running the machine on the stand in the ordinary way at a speed of 2,000 revolutions, with spark retarded and throttle half closed, the temperature on the exhaust side rose to 570°C. (a full red heat) in two or three minutes, while the inlet side remained comparatively cool. It would evidently be impossible to make any satisfactory tests under these conditions, as the exhaust valve would get burnt and the spring lose its temper. This was avoided by fitting

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a centrifugal fan on the fly-wheel enclosed in a case (shown in section in Fig. 1), with a duct delivering a blast on the exhaust side of the cylinder head, which not only made it possible to run the machine continuously on the stand without overheating the exhaust valve, but also doubled the efficiency of the machine when running on the road, especially at low gears. Using this fan, the temperature of the exhaust guide very rarely rose above 400°C., even at full throttle, with the spark retarded and the engine running continuously. Variation of speed did not produce much effect on the temperature, because the velocity of the cooling blast was increased in nearly the same proportion as that of the exhaust gases. The highest temperatures of the head were obtained at full throttle with the spark retarded, as in Fig. 5 (lower diagram), because the greater part of the heating effect on the exhaust valve depends on the outrush of the hot gases at the moment of exhaust, and not on the explosion temperature. With the spark advanced, and running under load, the temperatures observed were 20° to 30° lower for the same setting of the throttle, as the exhaust gases were much cooler.

In order more nearly to imitate, in the laboratory, the conditions of running on the road, a second fan was arranged in some of the tests, to deliver a horizontal blast from the front on the head and barrel of the cylinder, at a velocity of about 25 miles per hour when the engine was running at a speed of 2,000 revolutions. The cooling effect of this fan was somewhat greater than that of the natural draught due to the speed of the machine when running on the road on the high gear. It acted chiefly, like the natural draught, on the head and front and on the inlet side of the cylinder, the exhaust side being somewhat screened by the frame and the petrol tank. With both fans running the exhaust seldom rose above 300°C., or the inlet valve above 70°C. At full throttle the cooling effect of the partly vaporized petrol was so great that the inlet was kept as cool as 30° to 40° C., in spite of conduction of heat from the adjacent parts of the cylinder head. The suction of cool mixture is so effective in cooling the inlet side of the head, that no auxiliary cooling device at low gears is required on this side, beyond the natural draught.

Temperatures of the Combustion Chamber or Clearance.

The temperatures of the head or cover itself were measured on both the sheltered and exposed sides, and also the temperature of the barrel or curved surface above the end of the piston stroke. Without either of the fans, the exhaust side of the head and combustion chamber was 60° to 100° hotter than the inlet side after four minutes running light, when the engine began to show signs of overheating, and was stopped to avoid injuring the exhaust valve. With the fly-wheel fan to cool the exhaust side, the engine could be run continuously on the stand for any length of time at half or three-quarters load, and did not show signs of overheating till it had run for fifteen minutes at full load. Overheating took place on the inlet side, which was then 40° to 50° hotter than the exhaust side. With the fly-wheel fan it is impossible, even when running at full throttle on a low gear, to overheat the engine on the road, because the inlet side is fully exposed to the natural draught. Without the fly-wheel fan it was impossible to drive the fore-carriage at full throttle, even on the highest gear. Overheating rapidly took place on the exhaust side towards the back of the cylinder. Using the machine as a bicycle, with less than half the weight to drive, it was possible to employ a higher gear, and the natural draught was not obstructed by the fore-car. It was very seldom necessary to drive at full throttle, except for a short time, and there was never any trouble from overheating, even without the fan. It was found, however, that the fan, which weighed less than two pounds in all, produced quite a perceptible increase of efficiency, even with the bicycle, because the cylinder was kept cooler and at a more uniform temperature.

With both fans running on the stand, the temperature of the combustion chamber at full load never rose above 200°C. on the exposed side, or 260° on the sheltered side, away from the larger fan. The temperature of the greater part of the barrel on the front side was below 150 C., but rose so high as 200°C. on the sheltered side at the back. This was well below the temperature of overheating, which does not begin until a temperature of 300°C. is reached at the upper part of the piston stroke. The temperature of overheating depends, to some extent, on the quality of the oil used for lubrication; but most oils for air-cooled cylinders contain a residue which is sufficiently thick and non-volatile for the purpose at this temperature. Of the thinner qualities a larger quantity would be required, but the residue would probably be similar.

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Effect of Conduction.

It is well known that air-cooled cylinders of large diameter are more liable to overheat than small cylinders. The reason of this is not obvious at first sight, because the external cooling surface is increased in the same proportion as the internal surface receiving heat. The explanation is twofold. In the first place, the volume of hot gas in the cylinder increases in proportion to the square of the diameter; so that its average temperature in the larger cylinder remains higher throughout the stroke, and a greater quantity of heat per unit surface is communicated to the walls, as the gas is very far from being in a quiescent state. In the second place, the rear side of the cylinder is necessarily screened from the natural draught created by the motion of the machine. Cooling at the back depends chiefly on conduction of heat round the cylinder to the cooler sides. Even in the small C.G. cylinder, only 60 millimeters in diameter, the back may be as much as 50° or 100° C. hotter than the front. In a larger cylinder, say 80 millimeters in diameter, the difference of temperature required to carry away the heat by conduction may be more than twice as great. The back is more effectively screened on account of the size of the cylinder; the quantity of heat to be carried away by conduction is much greater, as explained above, than in the proportion of 80 to 60, and it has a greater distance to travel, as the diameter is increased. In any case, whether the engine is large or small, the rear of the cylinder will overheat sooner than the front. The remedy is evidently to arrange a cooling fan, somewhat as indicated in Fig. 1, to deliver a blast *across the back* of the cylinder, so as to keep the whole at a more nearly uniform temperature, and enable the motor to run at higher power or for a longer time without overheating.

Effect of Piston Convection.

Three of the thermo-couples were arranged in a line down the side of the cylinder, at the top, middle, and bottom of the piston stroke, in order to observe the distribution of temperature along the length of the cylinder. It would naturally be expected that, since the barrel surface at the top of the stroke is exposed to the full heat of the explosion when the gases are hottest and densest, and is also exposed to the high temperature for a much longer time than the lower part of the cylinder, there would be a very great difference of temperature between the top and bottom of the stroke. This would necessarily be the case if heat were transferred along the barrel by conduction only. At first sight one of the most curious results of the measurements was, that there was very little difference of temperature along that part of the barrel surface which was swept by the piston. When the top was at 200° C., the bottom of the stroke was at 180° C., a difference of only 20° in 70 millimeters. The reason of this, as explained in a previous paper on the Steam-Engine (Proc. Inst. C.E. 1898) is that, in a high-speed engine, convection of heat by the piston plays a much more important part than conduction, in the longitudinal distribution of temperature. The piston at the top of its stroke absorbs heat from the upper part of the barrel, and carries it very quickly to the lower end, where it is absorbed by the cooler walls. The greater the speed, the less the difference of temperature which can exist between the two ends. This action of the piston is most important in cooling the upper part of the barrel and distributing the heat over a wider surface. It is also an advantage in equalising the fit of the piston at the two ends of the stroke, which would be materially affected by expansion of the cylinder if the temperatures were very different.

It might naturally be expected that the lower parts of the cylinder would be relatively hotter when the spark was retarded, so that a greater part of the surface was exposed at the time of maximum temperature. The reverse, however, is the case. More heat is communicated to the *barrel* surface when the spark is advanced, owing to prolonged exposure; and this heat is distributed uniformly along the barrel by piston connection. Retarding the spark raises the temperature of the *head*, owing to the outrush of the hot exhaust, which does not much affect the barrel surface unless the valve chamber is at the side. The high temperature of the lower part of the barrel, due to piston convection, is an objection to the now prevalent fashion of omitting the lower ribs. This, however, is done chiefly for convenience of casting.

The Efficiency of Fan Cooling.

It is generally admitted, except in advertisements, that no air-cooled engine can work at full power continuously without overheating, except when running at a very high speed with a light weight on a level track, and with a high gear suitable only for racing. Where such a machine is required to carry two passengers and to climb hills on a low or medium gear, some makers fit a little fan to

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stir the air round the head of the engine, but the majority are reverting to water cooling as the only satisfactory method. It seems to be generally considered that the power wasted in driving the fan is greater than the power gained by more effective cooling. This misconception arises chiefly from inefficient methods of constructing the fan and applying the cooling blast. Some instructive experiments were made on the power required to drive the fans, in addition to the experiments already mentioned on the cooling effect produced. The fly-wheel fan absorbed so little power that it was very difficult to detect or measure the power absorbed. By employing a small electric motor to run the fly-wheel alone in its bearings (the piston and the rest of the engine gear being removed) with and without the fan attached, it appeared that the power absorbed at 2,000 revs. did not exceed 1-30th of a horse-power, which is quite negligible in comparison with other losses. This very small outlay of power, properly applied, makes all the difference, when carrying a load of five hundredweight up a long hill like Hindhead, between the motor overheating hopelessly and coming to a stop in the first half-mile, and racing up the whole three and a half miles at full throttle. The larger fan, which was used for the horizontal blast on the front of the engine when running on the stand, had separate bearings and was more easily tested. When mounted without a case in the manner usually adopted, so as to disturb the air in all directions round it, it absorbed 1-10th of a horse-power at 1,500 revs., and gave a blast of 12 to 15 miles per hour at the engine. When enclosed in a suitable case, arranged to concentrate the whole blast on the engine, it took only 1-20th of a horse-power at the same speed, and gave a blast of 25 to 28 miles per hour. That is to say, it worked at no less than four times the efficiency. It kept the engine rather cooler than when running full speed on the road, but it was better to be on the safe side in testing the engine on the stand. The velocity of the blast was found to vary directly as the speed of the fan; and the power required to drive it, nearly as the cube of the speed.

Indicated and Brake Horse Power.

The nominal horse-power of a motor is generally estimated from the cylinder dimensions and the speed. In some cases it is determined experimentally by a brake applied to the fly-wheel. The conditions of this test are somewhat artificial, and it is not surprising to find that the motor generally fails to develop its nominal power on the road. The power available at the road wheel is, of course, necessarily less than that given at the motor pulley, on account of losses in transmission; but even making allowance for losses in transmission, a large percentage of the petrol cars in the last reliability trials failed to realise as much as half their nominal horse-power on the test hills. The average for the small cars, taking only those which successfully completed the runs, was only 2-3rds of their nominal power. With the aid of accurate indicator diagrams, it is possible to measure the gross or indicated power directly, and to investigate sources of loss of power in a more satisfactory manner. The I.H.P. stated on the diagrams already given was obtained by subtracting the mean backward pressure of the compression stroke from the mean forward pressure of the explosion stroke, multiplying by the volume of the cylinder, and by the number of explosions per minute (half the number of revolutions, as there were no misfires) and by the appropriate factor to reduce to horse-power. The suction and back-pressure during the pumping strokes might have been deducted to obtain the nett indicated horse-power, but it is more convenient to include these with the mechanical losses. The maximum brake horse-power available at the engine pulley is most easily deduced from the indicator diagram by subtracting the indicated power when the engine is running light at the same speed with spark retarded, but otherwise under similar conditions. This neglects the effect of increased engine friction (included with transmission losses), but it has the advantage of eliminating certain small possible errors of the high-speed indicator. The accuracy of the gross indicated power was tested by belting the engine to an electric motor, and driving the combination by switching on the engine and the electric motor alternately. The power required was 1·52 h.-p. from the indicator measurements, and 1·48 h.-p. from the electrical instruments, the speed being the same in both cases. The small difference is readily accounted for by a very slight slipping of the belt on the engine pulley, when the engine was working.

The power required to run the engine light with the cylinder hot was also measured in the same way by an electric motor at various speeds, and the results were found to be in very satisfactory agreement with those deduced from the indicator diagrams at no load. The general results with regard to the

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maximum brake horse-power available at the engine pulley are shown in the curves in Fig. 7. The upper curve shows the gross indicated power at various speeds with full throttle and the best mixture. The lower curve shows the power running light under the same conditions. The middle curve shows the difference, or the maximum brake horse-power. There seems to be a very general impression that the brake horse-power increases in direct proportion to the speed.* As a matter of fact, it appears that even the gross indicated power does not increase in direct proportion to the speed. The curve is concave to the axis of speed, and shows a lower rate of increase at high speeds. The no-load curve, on the other hand, is convex to the axis of speed, and rises more steeply as the speed increases. The first effect is chiefly due to unavoidable diminution in the charge of gas at higher speeds: the second, to increased losses from suction, back-pressure, and friction, which are equally unavoidable. As a result there is a particular speed at which the brake horse-power is a maximum, which in the case of this particular motor is near 2,200 revolutions at full throttle under the ordinary conditions of use. No doubt it would be possible, by fitting lighter valves, and a larger carburettor, and by omitting the silencer, to get a bigger brake horse-power at a higher speed. But an artificial test of this kind would be of little or no value except for purposes of advertisement. It will be observed, moreover, that the indicated horse-power actually realised under the ordinary conditions of use, namely, 2·26 at 2,000 revolutions, corresponding to a mean effective pressure of nearly 80 pounds, is very good for so small an engine, without scavenging and with a very hot cylinder. With a much larger water-cooled motor, and 50 per cent. higher compression, the best mean pressure hitherto realised is only about 90 pounds. In a small high-speed engine the losses due to the action of the walls are necessarily greater, and one can hardly expect to realise the same effective pressure.

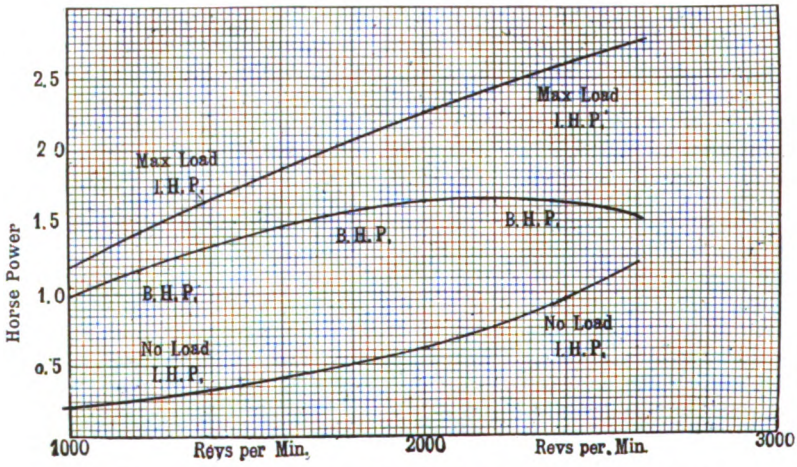

FIG. 7.—GRAPHIC REPRESENTATION OF RELATION BETWEEN HORSE-POWER AND SPEED.

Efficiency of Transmission.

A most important question for the user of a motor cycle is the power actually realised at the road wheel, which depends on the efficiency of transmission, as well as on the efficiency of the motor. Very little is known about this point, as it is rather difficult to test under the conditions of use. In order to get some idea of the power required at the road wheel, an epicyclic gear of special construction was fitted to the cycle (in addition to the ordinary Garrard two-speed gear), giving a practically continuous range of gears from 8 to 16 revolutions of the engine to one of the road wheel. This was arranged in such a manner that it could also be used as a transmission dynamometer to measure the actual pull on the driving wheel when the machine was running on the road. The test was made in both directions along the same stretch of road, to eliminate the effect of slight gradients and of wind resistance. A simple speed indicator was employed to deduce the power. With the fore-carriage attachment and a total load of five hundredweight, it was found that a pull of 18 to 20 pounds was required to drive the machine on a good level road at a speed of 20 miles per hour. This is equivalent to

* This misconception has probably arisen from the very general use of carburettors which require flooding to start, and will not give a good mixture at low speeds.

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one horse-power. At this speed the engine was running well within its power, but it was clear that a good deal was lost in the transmission. The result of the road test was verified by measuring the power developed by the engine on the stand with a special brake applied to the back-wheel tyre. It was found that the engine actually gave a little over one horse-power on the back wheel under the conditions used in the road test. At full throttle it would do rather better, the maximum realised being 1·15 H.P. on the wheel, against 1·64 B.H.P. at the engine, giving an efficiency of 70 per cent. This is a very fair efficiency of transmission, considering that the power was transmitted through four chains and two epicyclic gears, and that the transmission loss includes increased engine friction. The chains were rather worn and rusty, and the gears had run 3,000 and 4,000 miles respectively. Better results might have been obtained with new chains and all the gear in first-class condition, but the above may be taken as fairly representing the conditions of ordinary use. A single belt would give as much loss as the four chains, and would not work at a gear of 16 to 1, besides giving far more trouble in dirty weather.

There are many other questions of interest to the motor cyclist at the present time, which might profitably be discussed in the light of the information afforded by the indicator diagrams and the temperature measurements. Such are :—The relation of fuel consumption and richness of mixture to cylinder temperature and useful effect obtained. Loss of power due to suction and back-pressure. Overheating and loss of power due to leakage of valves, or piston rings, or head joints. The advantages of automatic, as compared with mechanically operated inlet valves, or *vice versâ*. The velocity of the explosion and the power obtained as related to the character of the spark, the amount of advance, or the addition of other substances to the petrol. The influence of compression on the economy. The advantages of multiple as compared with single cylinders. The efficiency of different kinds of lubricants, and a host of other questions. Some of these are now under investigation, and may be discussed on a future occasion. The most important point for the motor cyclist is to secure the maximum of power and flexibility with the minimum of weight and other inconveniences. With this object, the first essentials are a variable speed gear of wide range, and some efficient method of cooling to prevent overheating at low gears. It is no use to fit a mechanical inlet valve in order to get more power, when the automatic valve already overheats the motor. It is unscientific to double the weight and power of the machine in order to climb a few hills, when the same result, with far greater flexibility of control, can be secured by a variable gear. It is unnecessary to resort to the weight and complication of water cooling when a light fan will do all that is required. How this method has been applied in a particular case is shown in the present article, and the principles underlying the application have been explained so fully that there should be no difficulty in applying the method with satisfactory results in other cases.

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A POSSIBLE ADVANCE IN "INDUSTRIAL CHEMISTRY."

By BERESFORD INGRAM, B.A., F.C.S.

WONDER whether any of the readers of "Technics" are aware that a considerable for tune awaits anyone who can prepare an enamel which will adhere to an iron or metal surface and stand the test of time.

The enamels used for advertisement purposes are fairly satisfactory; but their permanency depends almost solely on the fact that the variations in temperature which they experience are gradual and between very small limits.

But what about those articles which are subjected to sudden and frequent changes of temperature, such as baths, lavatory basins and the insides of water pipes? I am in a position to state that tens of thousands of pounds have been spent in endeavouring to prepare an enamel which will not "crase" after constant use under these conditions.

The best enamelled baths will stand the test of alternate heating and cooling for two or three years, but after that time they will almost certainly "crase" a little; the next sudden change of temperature "raises the crase"—then a slight blow is more than sufficient to chip a piece off the surface, and in a few weeks the bath is worse than useless.

A well-known firm of sanitary engineers in the North of England has been enamelling baths, by the primitive method of superposing coats of paint, for the last thirty years; and during that time no more than half-a-dozen baths were returned as imperfect. About two years ago, this firm built a porcelain enamelling plant at a considerable cost, engaged an expert from a well-known Scotch firm in the same trade, and also a chemist to superintend the quantitative mixing of the constituents of the glazes. The baths turned out were pronounced "first-class" and the best prices were obtained.

But now, the baths are coming back one and two at a time, and already the loss has crept into thousands of pounds. This experience is not singular, since many firms have had to give the process up entirely, and are now devoting capital to obtain a glaze which will permanently adhere to the metal casting.

There are so many stages in the process of enamelling a bath, that it is only possible to mention the most obvious. These are:—

(*a*) The surface of the casting must be properly prepared, so as to make the "base,"* which is first burnt on, permanently adhesive.

(*b*) The temperatures at which the "base" is burnt on, and the enamel afterwards.

(*c*) The temperature at which the bath is allowed to cool. (If cooled at all quickly it crases immediately.)

(*d*) Intramolecular action in both base and glaze.

(*e*) Subsequent crystallisation of the vitreous constituents.

(*f*) Differences in the co-efficients of expansion of the enamel and the metal.

These indicate a few of the possible causes of the present failure, which only research can remedy. On the other hand, it is definitely known that different thicknesses in the iron, setting up different rates of expansion, are certain to start the "crase."

Again, given a perfectly uniform casting, there seems to be some unaccountable law which causes different rates of expansion on flat and on curved surfaces.

The enamels themselves also give a great deal of trouble, insomuch that two castings "baked" under the same conditions, with exactly the same glaze, will not produce an enamel of precisely the same tint in each case. Added to all this, the enamel itself, unless "dusted on" with the utmost care, will not melt to the same degree of mobility, and thus adds to the defect of unevenness the almost certain probability of "crasing."

The New Factory Act of February, 1904, has further complicated matters by placing a limit on the percentage of lead and volatile compounds present in the glaze. This directly affects the economy of the process, since the lead compounds are so essential to produce a low melting-point. The temperature necessary for the burning is almost a white heat, and the "firing" is already an extremely expensive item in the cost of production.

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* The "base" is the first coat which a bath receives when enamelled—it has all the constituents of ordinary glass.

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THE MICROSTRUCTURE OF METALS.

By PERCY LONGMUIR.
Carnegie Research Scholar

AT a meeting in support of technical training, some years ago, one of the speakers, in describing his conversion from the ultra-practical to the scientific aspect, said that when he first heard of chemical methods applied to steel-making, his words were: "What! make steel in a druggist's shop? Never!" But, as the speaker reminded his audience, manufacturers had, by sheer necessity, been compelled to adopt scientific methods of controlling their manufacturing operations. Chemical control of steel-making and kindred metallurgical processes is now universal, and practically every metallurgical work is equipped with a works laboratory. Not only have chemical methods taken a firm hold on industrial metallurgy, but to-day a newer and independent form of examination is being adopted by the more progressive works. Chemistry has contributed largely to metallurgical advance; so, too, the material benefits of this newer method—that of microscopical examination of metals—are exceedingly promising, the results already obtained offering much information of direct practical value. Naturally the results of a microscopical examination are only of value when compared with the chemical composition. Knowing the exact amount of each element present, the next step is to ascertain the mode of existence, or particular method of distribution of these elements in the metal. This is facilitated by the fact that a suitable magnification reveals the structural arrangement, or, as it has been more aptly termed, the internal architecture of the mass.

The internal structure is not comparable with the appearance presented by a broken surface of the metal, for the method employed to break the metal influences to a large extent the character of a fracture. Further fractures, which to the eye are practically uniform, are often found, when examined at a higher magnification, to be of a very composite character. Fractures do undoubtedly show the general grouping of the crystals; but the particular arrangement and the distribution of impurities are far beyond unaided visual recognition. Thus Fig. 1 reproduces three fractures of ordinary steel bars. The structure of these bars is represented in Fig. 2.

FIG. 1.—FRACTURES OF STEEL.

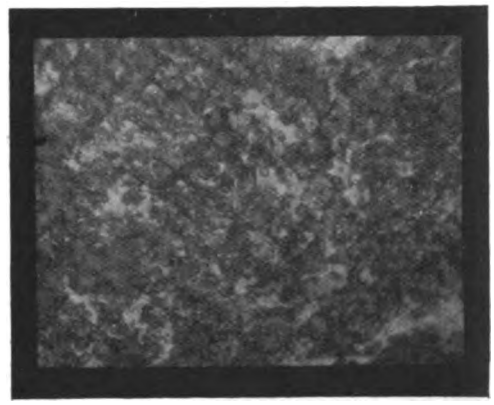

FIG. 2.—STRUCTURE OF STEEL SHOWN IN FIG. 1: MAGNIFIED 260 DIAMETERS.

The preparation of sections of metal for microscopical examination is in many cases a tedious operation. As a rule, harder metals are prepared more easily than softer ones, owing to the difficulty of eliminating scratches in the latter. A small piece of the metal is cut from a larger mass, this piece forming the "section," one surface of which must be a plane finished perfectly smooth. It is then freed from minute scratches on a series of emery papers of succeeding fineness, and finally polished on kid skin on which is sprinkled a little jeweller's rouge. When free from scratches, the structure is developed by the agency of a suitable etching medium. These mediums vary in character, but as a rule consist of very dilute acids which, acting differentially on the various constituents of the metal, throw certain of them into greater prominence than others. In the case of a pure metal the crystal junctions are more

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rapidly attacked than the crystals themselves. The process of etching a metallic section thus bears some analogy to the method of developing a photographic dry plate. When the desired intensity or contrast has been obtained the section is washed in water and dried, and is then ready for examination.

Chemically pure metals are in mass built up of pure crystals; a section of such a metal will, therefore, show only a series of crystal junctions. These junctions are well shown in Fig. 3, which represents the structure of pure copper at a magnification of 40 diameters. The junctions shown in this photo-micrograph are typical of any pure metal such as gold, silver, or iron; but whilst representing the type of crystal junctions met with in all pure metals, it does not necessarily represent the *size* of the crystals, as a comparison of Figs. 3 and 7 will readily show.

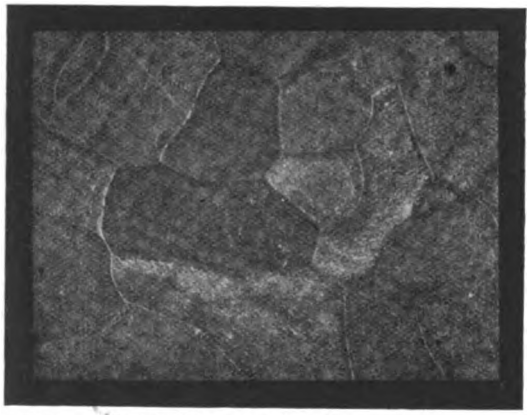

FIG. 3.—STRUCTURE OF PURE COPPER MAGNIFIED 40 DIAMETERS.

However interesting the study of the structure of chemically pure metals may be, the most valuable fruits of this new science of metallography are found in a study of commercial metals and alloys. It need hardly be said that comparatively few of the commercial metals are of absolute purity. In many cases traces of impurities are present in the metal in spite of the vigilant care exercised in reducing them from their ores. In other instances additions are purposely made to the metal, in order to impart properties not otherwise possessed by the metal. It has been stated already that the physical properties of any metal are a function of its chemical composition, but to attain a full knowledge of the effect of composition the structure must be examined. The characters of the various associations of other elements with the metal are unmistakably written in the structure; therefore it only remains to interpret the structure correctly, in order to attain the knowledge which chemical analysis does not always supply.

One of the most fascinating problems of metallurgy is found in the enormous influence exerted on a mass of metal by the presence of mere traces of other elements. These traces are, in many cases, exceedingly minute, and out of all proportion to the mass of metal in which they are held. For instance, the presence of a few tenths of one per cent. of carbon produces an enormous change in the character of the metal iron, and a few hundredths of one per cent. of sulphur, associated with this iron, determine its industrial success or failure. The presence of a mere trace of bismuth in copper produces a remarkable change in the electrical and mechanical properties of the metal, both being very seriously impaired.

The minuteness of these traces is alone sufficient to prove that the change in properties is not due to the individual action of the element added. Thus, by no stretch of imagination can it be imagined that the diffusion of a few tenths of one per cent. of carbon through iron—in the form of free carbon—will result in the product steel. But if this carbon chemically combines with a portion of the iron to form a definite carbide of iron, which, in turn, is distributed through the mass of ductile iron, then the marvellous change in properties may be readily understood. That this combination does take place will be shown later; for the present it may be stated that, as a rule, the addition of a foreign element to a pure metal results in the formation of a definite chemical compound, which usually possesses essentially different properties to those of its constituents. Thus, carbide of iron is exceedingly hard and brittle, possessing none of the properties of ductile iron on the one hand, nor yet, on the other, does it bear the least resemblance to carbon. Evidently, too, by the formation of a compound, the volume of the added element is increased, for chemical compounds always form in a fixed ratio of one element to the other. Thus one part of carbon associates with three parts of iron to form the definite carbide F_3C. The volume occupied by this carbide is therefore greater than if the carbon existed in the metal in its elementary state.

The properties of any metal to which an element has been added become, in some

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measure, an index of the properties of the compound formed by the metal and the element. If the compound be fragile, then the mass will be brittle, owing to the distribution of the fragile compound through it. On the other hand, the compound may possess properties which, distributed through the mass, go to bind and strengthen the structure, thus increasing the mechanical value of the whole. Ignoring for a moment alloys of iron and carbon, it may be stated that any mixture of metals, on cooling from a molten state, passes through a variety of conditions. With a molten metal containing a trace only of an added element, the first feature of note on cooling is that of the formation of the pure crystals, which, in the act of crystallising, reject the impurity to the crystal boundaries. In other words, two distinct freezing points are shown, viz :— that of the pure crystals and that of the compound. On final solidification the pure crystals will each be surrounded by an envelope of the compound, a feature shown sectionally as a meshwork in Fig. 4. This structure is very typical of the majority of pure metals, to which traces of foreign substances have been added. Translating it into the solid, it will be seen that the strength of the metal is now dependent entirely on the character of the envelopes of the compound. No matter how thin the investing membrane may be, it most effectually isolates the pure crystals, and, according to its character, contributes either to fragility or to an increased mechanical strength. Thus it may be possible, in certain cases, for the individual crystals to be perfectly ductile, whilst the mass is completely brittle. This feature has been very forcibly illustrated by Professor Arnold in the following manner. A bar of pure gold showing crystal junctions common to a pure metal (Fig. 3) after bending through 1,720 degrees of flexion remained unbroken. A bar of the same gold, containing only two-tenths of one per cent. of bismuth, and showing the network structure familiar to pure metals containing traces of impurity, was so brittle that it broke without showing the least tendency to bend. In other words, the well-known ductility of pure gold is completely neutralised by the presence of this minute quantity of bismuth. Yet, as Professor Arnold has further shown, the crystals of gold, when separated from the gold-bismuth compound, possess all their original ductility, and may be beaten out into thin gold leaf. Thus, from a metal which in mass is so brittle that it fractures like glass, individual crystals may be obtained which permit of being beaten out into leaf of a thickness less than a single page of this magazine. So much for the influence of mere traces of impurities.

Turning to the wider question of industrial alloys, other features present themselves. As a rule, these alloys contain three or more constituents; and whilst one metal, copper for instance, may predominate, the other members of the alloy are usually present in appreciable quantity. Obviously, then, the structure of these alloys is more complex in that there may be several distinct compounds present. When the trace added to a molten metal is replaced by an appreciable quantity of another metal, the compound formed may be sufficient to saturate the mass. In other words, the pure crystals of metal are replaced

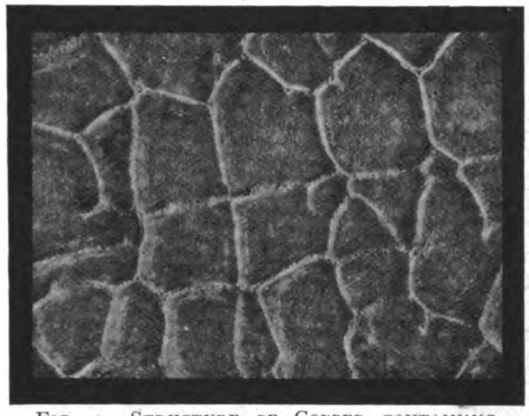

FIG. 4.—STRUCTURE OF COPPER CONTAINING 0·2% IMPURITY: MAGNIFIED 40 DIAMETERS.

by compound ones, the meshwork of Fig. 4 increasing in bulk with successive additions until it forms the whole structure. Thus, copper alloyed with about 34 per cent. zinc is known as true brass, and consists of the copper-zinc compound Cu_2 Zn.

But when the zinc is increased beyond this content, the structure of the alloy becomes more complex, and, in all probability, two distinct compounds of copper and zinc are formed. An alloy of copper with 40 per cent. zinc will consist of crystals of Zn_2 Cu distributed in a matrix of Cu_2 Zn. Such an alloy is known as Muntz metal, and the structure of a typical sample is reproduced in Fig. 5. The light portions represent the yellow compound, or true brass, whilst the dark ones are those of the probable compound Zn_2 Cu.

To give any adequate representation of the structures of all industrial alloys would occupy far too great a space; for the present, Fig. 5

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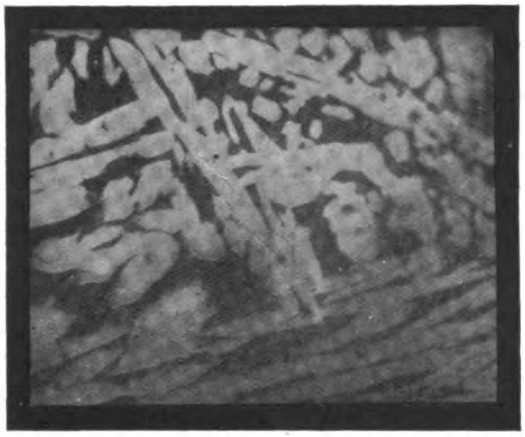

FIG. 5 —STRUCTURE OF MUNTZ METAL: MAGNIFIED 240 DIAMETERS.

may be taken as typical of brasses high in zinc, and Fig. 6 fairly represents the structure of high quality commercial gun-metals. In gun-metals, the zinc of brasses is replaced by tin, though the content of the latter seldom exceeds 10 per cent. The tin is structurally present in the form of a compound of copper and tin of the formula Cu_4 Zn.

Turning to the metallography of steel, which possibly, owing to the wider application of the metal, has received more attention than has been devoted to general alloys, many features of interest present themselves. Steel may, for our purpose, be described as an alloy of iron and carbon, poured in a fluid condition into an ingot or other shape for the production of a malleable mass. The greater the content of carbon the greater the hardness and the less the malleability; thus, above a certain percentage of carbon, the alloys pass out of the products known as steel, and merge into those known as cast iron. Practically this limit of carbon is found at 1·5 per cent., which represents a razor steel; though certain special varieties of steel contain up to 2 per cent. of carbon. However, beyond this latter figure, the metals are essentially cast irons: that is, metals possessing no malleability, and exceeding brittleness. The hardness of a steel increases continuously with increasing additions of carbon, whilst at the same time the ductility steadily decreases until it finally disappears. The tenacity of the steel steadily increases with increasing content of carbon, until at a certain percentage a maximum is reached, from which the tenacity again falls with successive increments of carbon. It will be readily seen that this alteration of mechanical properties, produced by varying the content of carbon, is of wide practical value; it is recognised to such an extent that every class of steel has its own specific content of carbon. To some extent the influence of carbon on the mechanical properties of iron is shown in the following table, which gives the mechanical properties of irons containing 0·1 per cent. and 1·0 per cent. of carbon respectively:—

Material.	Content of of Carbon.	Breaking Load in Tons per sq. inch.	Elongation % on 2 inches.	Contraction of Area %
Mild Steel	0·1 %	20·0	50·0	70·0
Tool Steel	1·0 %	60·0	5·0	10·0

The enormous change produced in the mechanical properties of iron by the presence of comparatively small amounts of carbon is very familiar to steel makers and steel users. Indeed, so well is this influence of carbon recognised, that in works practice steels are classified in grades, which, in many cases, vary only by 0·1 per cent. If, then, the microscope has any application in the field of metallurgy, it should be most evident in the particular case of iron and carbon alloys; and an examination of the metallography of steels is alone sufficient to justify this application.

In an earlier part of this article, when describing the cooling from fluidity of a pure metal containing a trace of impurity, it was shown that the pure crystals separate first, and in so doing, reject the impurity to their boundaries, as seen in Fig. 4. These conditions, whilst generally applicable to all metals, do not hold good in the case of iron

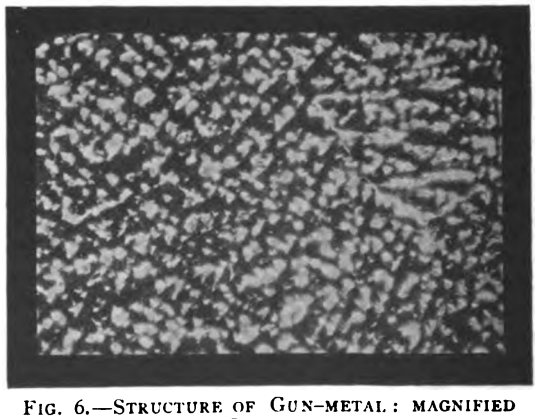

FIG. 6.—STRUCTURE OF GUN-METAL: MAGNIFIED 34 DIAMETERS.

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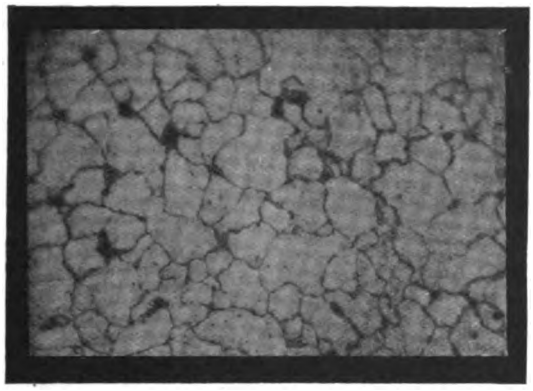

FIG. 7.—STRUCTURE OF PURE IRON: MAGNIFIED 212 DIAMETERS.

and carbon alloys, for in these alloys crystallisation does not occur until a temperature considerably below the solidification point has been reached. Turning to Fig. 7, which represents the purest commercial iron obtainable, the general resemblance of the crystal junctions to those shown in Fig. 3 will first be noted: in comparing the size of the crystals, the difference in magnification must be remembered. Apart from the crystal junctions, however, several dark knots are visible, which represent the minute trace of carbon present. Carbon present in a steel is always in the combined form; that is, it occurs as a definite carbide, Fe_3C. In the simultaneous presence of manganese, chromium, or certain other metals, double carbides are formed. For convenience, these hard carbides are micrographically known under the one term of "cementite." On the other hand, pure iron, such as that shown, Fig. 7, is known as "ferrite." A mixture of ferrite and cementite is known as "pearlite," Pearlite often consists of alternate striæ of ferrite and cementite, and in such a form gives a most magnificent play of colours resembling those of mother-of-pearl; hence the term "pearlite" which, in reality, is a contraction of Dr. Sorby's "pearly constituent."

In addition to this laminated form, pearlite may occur in a granular form; that is, cementite embedded in ferrite. Below a certain content of carbon the cementite of a normal steel is always in the form of pearlite. Thus the dark knots of Fig. 7 represent pearlite, the composite structure of which is not reproduced in the photograph. The content of carbon in this iron is actually 0·05 per cent., and the distribution of so minute a trace in its compound form is readily visible. As the amount of carbon is increased, the pearlite is increased at an equal rate; evidently this must be accompanied by a corresponding disappearance of ferrite from the structure. Thus, in a series of ascending carbons, a point will be reached at which ferrite is entirely absent and the whole structure composed of pearlite. This point has been very firmly established by Professor Arnold at a content of 0·89 per cent. carbon. Such a steel in the normal condition consists entirely of pearlite, and corresponds with the saturation point of iron for carbon. In accordance with these views, a steel containing 0·45 per cent. carbon should possess a structure in which pearlite and ferrite are present in similar quantities. A glance at Fig. 8 will show that this is actually the case. The dark areas of this photo-micrograph represent the pearlite, whilst the lighter ones are those of ferrite. It is hardly necessary to depict the structure of a saturated steel, for the whole of it consists of pearlite, and such a structure is the nearest approach to homogeneity possible in normal steels. A further interesting feature is the structural disposal of the surplus carbon, once the saturation point of 0·89 per cent. has been exceeded. This is readily shown in Fig. 9, in which the white cell walls represent pure cementite. The composite character of the pearlite within the cells is well shown. In process of crystallisation, this pearlite behaves in an analogous manner to that of a pure metal, in that it rejects the surplus cementite to the crystal boundaries, thus forming a meshwork similar to that of Fig. 4.

In considering the mechanical value of these structures, it must be remembered that cementite is exceedingly hard and brittle, whilst ferrite is very soft and ductile. In an

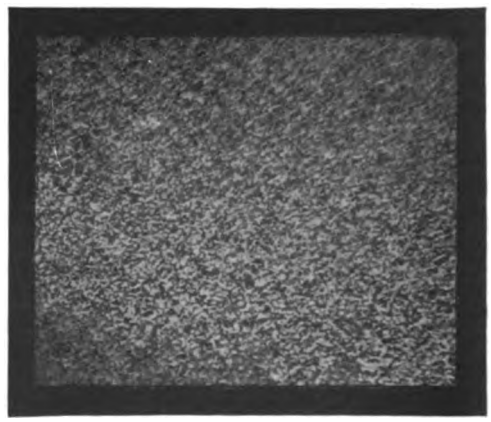

FIG. 8.—STRUCTURE OF FORGED STEEL CONTAINING 0·45% CARBON: MAGNIFIED 43 DIAMETERS.

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unsaturated steel the cementite is not structurally free; but is associated with ferrite to form pearlite areas, which are distributed in juxtaposition with ferrite throughout the structure. It is at once evident that the brittleness of the cementite is modified by the ferrite; and whilst the former tends to strengthen the mass by making it more tenacious, the latter, by its association with the cementite, contributes towards ductility,

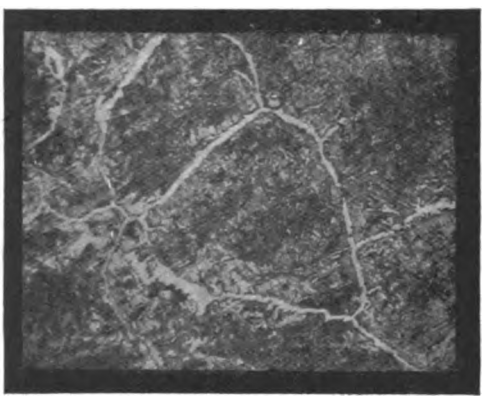

FIG. 9.—STRUCTURE OF UNFORGED STEEL CONTAINING 1·5% CARBON: MAGNIFIED 36 DIAMETERS.

according to the amount present. However, once the saturation point is exceeded and structurally free cementite appears, ductility and resistance to shock rapidly vanish; when the cell walls of cementite attain an appreciable thickness the tenacity also commences to decrease.

These features are of practical importance in the manufacture of cutting tools. Thus a chisel for cutting metals (which of necessity must carry a cutting edge and yet submit to a certain amount of shock, as represented by the blows of a hammer), contains no structurally free cementite. In other words, its content of carbon is approximately 0·9 per cent. A file for cutting metals, which has comparatively little shock to withstand, contains 1·2 per cent.; and a razor, the chief essential of which is a keen cutting edge, contains 1·5 per cent. carbon. Razors, of course, have no shock to meet, hence brittleness is immaterial, and the surplus cementite by its hardness contributes to the keenness of the cutting edge. When the carbon content exceeds 2 per cent. the products are known as cast iron. Chronologically, a study of cast iron ought to precede that of steel, but absolute sequence has, in the present case, been sacrificed to clearness, since the structures of steel are much less complex than those of the impure cast iron. Reversing this order, it will be seen that the cast irons are the first product obtained by the reduction of iron ores, and represent the first stage in the steel or iron-making process.

It is the distribution of carbon in cast iron which determines its quality. Broadly speaking there are two grades—those of white and grey cast irons respectively. In the white irons, the carbon exists in definite combination with the iron, and therefore its structure will show a comparatively large amount of cementite. Referring for a moment to Fig. 9, it will be seen that as the amount of cementite increases, so will the thickness of the cell walls, until eventually they form areas in juxtaposition with the pearlite areas. The structure of a typical white cast iron will therefore consist essentially of cementite and pearlite, as shown in Fig. 10. The black portions of this photomicrograph represent pearlite, and the white portions cementite. An iron possessing such a structure will be exceedingly hard and brittle; it is, in fact, impossible to drill or file it with ordinary tools. On the other hand, a grey

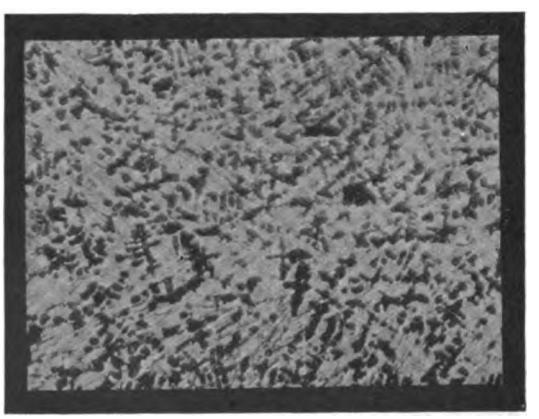

FIG. 10.—STRUCTURE OF WHITE CAST IRON CONTAINING 3·5% CARBON: MAGNIFIED 39 DIAMETERS.

iron containing a similar amount of carbon readily admits of machining, a distinction due entirely to the difference in condition of the carbon. Whilst the carbon of the white iron is in the form of hard cementite, that of the grey iron is present in the free state as elementary carbon, and therefore has a mechanical, and not a chemical effect. This free carbon, or graphite, is shown in the long plates of Fig. 11. These plates have no chemical effect, since they are not combined with the iron; but they have a mechanical effect

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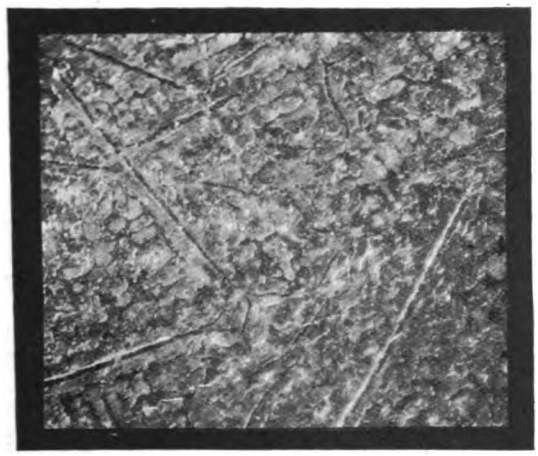

FIG. 11.—STRUCTURE OF GREY CAST IRON CONTAINING 3·5% CARBON, CHIEFLY IN THE FORM OF GRAPHITE: MAGNIFIED 40 DIAMETERS.

in that they destroy the continuity of the mass, thereby leading to cleavage, either under gradually applied stress or sudden shock.

The influence of heat treatment on metals is hardly appropriate to this present survey, but one feature must be noticed. The cementite of Fig. 10 is extremely sensitive to suitable heat treatment. Thus, if a casting of white iron be heated for a length of time, the cementite is decomposed into its constituents, iron and carbon. If the heating be followed by slow cooling, the cementite does not again form, and the resulting casting readily permits of filing, drilling, or other mechanical operations. A singular feature is, that the carbon is not deposited in the long plates, such as are shown in Fig. 11, but appears in a fine state of distribution through the structure. Fig. 12 represents the structure of the same iron as that of Fig. 10 after heating to redness for a period of seven days, followed by slow cooling. A comparison of the two photo-micrographs shows at once the enormous structural change due to this form of heat treatment. The typical crystal junctions of ferrite will be readily noted in Fig. 12: areas of pearlite are also visible; whilst the dead black portions represent the fine amorphous carbon due to the decomposition of the cementite.

The susceptibility of metals to heat treatment is well shown in this last example. Not only are metals sensitive to the influence of heat below their fusing points, but they are also modified by the influence of work, such as rolling, forging, wire drawing, and the like. These modifications, due to treatment or work, are indelibly written in the structure, and require only a suitable magnification to reveal the particular method of treatment. Herein lies a valuable feature of microscopical examination, since the condition of the metal may be recognised at a glance. But by far the most valuable feature is found in the clear light thrown on to the structural distribution of the various elements or impurities present in the metal. Whilst chemical analysis accurately reveals the ultimate composition in the majority of cases, it does not indicate the combinations present in the metal, owing to the fact that these compounds are necessarily broken up by the analytical methods employed. From the illustrations given, it will be seen that the properties of a metal depend, not so much on the amount of each constituent present, as on the particular distribution of the constituents, in compound form, through the mass. The microscope gives a means of studying this structural distribution, thereby offering trustworthy guidance towards fuller knowledge of metals and alloys.

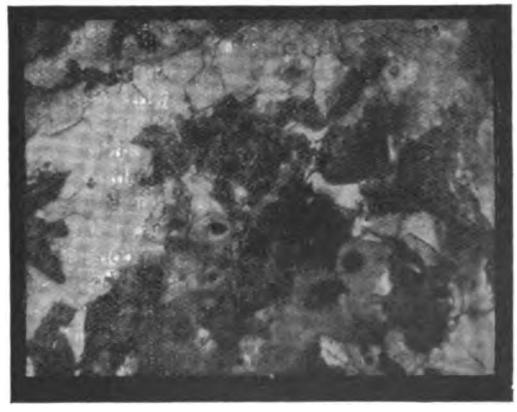

FIG. 12.—STRUCTURE OF SAME IRON AS FIG. 10 AFTER ANNEALING; SHOWING CRYSTALS OF FERRITE, AREAS OF PEARLITE, AND FREE CARBON: MAGNIFIED 210 DIAMETERS.

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THE ESTIMATION OF CARBON IN IRON-CARBON ALLOYS.

By H. C. H. CARPENTER, B.A., Ph.D. of the National Physical Laboratory.

IN the following article an attempt will be made to gauge the limits of accuracy of the most trustworthy methods of estimating the various forms of carbon in the commercial alloys of iron and carbon, viz., steel, pig-iron, etc. For details of the methods, readers are referred to Brearley and Ibbotson's "The Analysis of Steel-works Materials," and Blair's "The Chemical Analysis of Iron."

In addition to the errors of the particular chemical method employed, there is the well-known difficulty of obtaining a thoroughly representative sample of the material to be analysed. The reason for this is, that the alloys of iron and carbon are seldom homogeneous or uniform mixtures. A steel containing anything up to about 0·9 per cent. of carbon, hardened from a sufficiently high temperature (viz. 900 C.) has a homogeneous physical structure. An unhardened steel containing about 0·9 per cent. carbon consists of a uniform mixture of iron and carbide of iron in fine plates called pearlite. But these are exceptional instances. Rail steel, with about 0·4 per cent. carbon, consists of pearlite in an excess of ferrite (iron). Grey pig consists of a mixture of pearlite (soft) with graphite (soft), and an excess of carbide of iron. The white irons contain pearlite, with a large excess of iron carbide.

There is less difficulty in obtaining an average sample of the low carbon unhardened steels. In this case the material is soft and the drill bores out long shavings. In the case of high carbon iron, a powder consisting of fine and coarse particles results; the most accurate results are obtained by sieving the powder, weighing the fine and coarse particles, and thus determining their relative proportion, and estimating the carbon in each. Another good plan is to grind the powder in a porcelain mortar until it passes through a fine mesh.

There can be little doubt, however, that a method of sampling, in which the error is less than that of the chemical method of determining the total carbon, has still to be found.

The Estimation of Total Carbon.—The method which is generally accepted as being the most accurate involves the solution of the material in potassium-copper chloride liquor, and the combustion of the carbonaceous residue in a stream of oxygen, the carbon being weighed as carbon dioxide. According to the experiments of the American members of the International Steel Standards Committee, accurate results are obtained only if the potassium-copper chloride is acidified with hydrochloric acid at the outset. On the other hand, some hold that this causes a loss of carbon in the form of hydrocarbons, and that it is not safe to acidify the liquor until the steel or iron is entirely dissolved, the purpose of the acid being to dissolve precipitated copper.

In either case remarkably concordant results can be obtained by this method. The following figures have come under the writer's experience, using Blair's method:—

1.	0·120	0·169	0·798	0·805	per cent.
2.	0·120	0.169	0·797	0·803	per cent.

It is probably not overstating the case, to say that this method, *per se*, is capable of giving an accuracy of one part in a thousand. The errors of sampling are, however, seen in the fact that, taking the whole range of iron-carbon alloys, duplicate analyses show, on an average, differences of about 2 per cent. on the absolute amount. There is an uncertainty of at least one unit in the second place of decimals in most cases; and it is frequently more.

The method of direct combustion in the wet way (*vide* Brearley and Ibbotson, pages 11-13) is probably capable of about the same accuracy.

The Varieties of Carbon.

Ledebuhr, in 1893 (*Journal Iron and Steel Institute*, vol. ii, page 53), distinguished four modifications of carbon:—(1) graphite carbon; (2) temper carbon; (3) carbide carbon; (4) hardening carbon; and although Nos. 1 and 2 have certain properties in common, they cannot be regarded as identical.

Graphite carbon is a constituent of grey pig iron. It occurs in the well-known tabular hexagonal scales, and is formed by the crystallisation of carbon from *fluid* high carbon irons, when the rate of cooling is sufficiently slow.

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Temper carbon is produced when white pig iron is annealed at about 1,000°C., owing to the decomposition of iron carbide at this temperature. In contradistinction to graphite carbon, it appears to be completely amorphous. It is the form in which carbon separates from a *solid* high carbon iron.

At the present time there is no method of estimating graphite carbon in the presence of temper carbon, and *vice versâ*, owing to the great similarity of their chemical properties. If, therefore, they occur together, they have to be estimated together. The method which gives the most uniform, and probably the most accurate results, consists in dissolving the material in nitric acid (specific gravity 1·2), thus removing hardening carbon and carbide carbon, and following the directions given by Blair (page 167).

The accuracy of this method is probably not far short of, if indeed it is at all inferior to, that described for total carbon. The chief uncertainty is as to how far these two forms of carbon are insoluble in nitric acid. According to Jüptner von Jonstorff (*Journal of the Iron and Steel Institute*, 1897, No. 1, page 249), graphitic and temper carbon are oxidised "slowly, but completely," by boiling nitric acid. Further, the uncertainty, due to difficulties of sampling, is more pronounced in graphite determinations than in the case of the other forms of carbon.

The chief chemical difference between graphite and temper carbon is that when the high carbon iron is treated in such a way as to produce malleable castings (*e.g.*, by heating it with haematite), the temper carbon is oxidised, while the graphite remains unaltered or very nearly so. Similarly if the iron is heated to redness in hydrogen, the temper carbon is more rapidly removed, in the form of a hydrocarbon, than the graphite carbon. But in neither of these cases is the distinction sufficiently sharp to admit of an accurate means of separation. And it must be admitted that, in the present state of our knowledge, there seems no prospect of obtaining a separation by chemical means.

Carbide Carbon.—This form of carbon is found in annealed steels and pig-irons. In alloys wherein the carbon does not exceed 0·9 per cent., it occurs in thin plates, while with higher percentages it is found in addition as comparatively large and irregularly shaped pieces. The carbide was isolated by Abel, and has recently been thoroughly studied by Mylius, Förster and Schoene.* The analytical numbers correspond to the formula Fe_3C, but the molecular weight is unknown.

A gravimetric method of estimation is given by Ledebuhr and Müller.† It is based on the assumption that the carbide is undecomposed, when the iron is dissolved in extremely dilute acids, hardening carbon being evolved as gaseous hydrocarbons, carbide, with graphite or temper carbon being left behind. The two latter are determined independently, and the carbide obtained by difference. Any error in their determination would appear in that of the carbide. Further, it has been shown that the carbide is decomposed by the most dilute acids (even acetic acid) and the greatest care must be taken to preserve it from contact with air, owing to its liability to oxidise.

It appears almost impossible to state the accuracy of this method. Probably it does not give results nearer than 3 or 4 per cent.

A method proposed by Jüptner von Jonstorff (*loc. cit.*) of estimating the carbide colorimetrically, by dissolving in dilute nitric acid at 80° C, comparing with a solution of known carbide content, is certainly not accurate to nearer than ± 5 per cent.

Hardening Carbon.—The chemistry of this important and interesting form of carbon has still to be elucidated. As the name suggests, it appears in hardened steels. Microscopic investigation has shown that hardened steels with less than 0·9 per cent. carbon are almost homogeneous substances. The structures developed by etching are crystalline, and at the present time the view is held that hardened steels consist of solid solutions.

Dilute hydrochloric or sulphuric acid causes the evolution of a complex mixture of hydrocarbons, and it is very desirable that this reaction should be thoroughly investigated and explained. It has a vital bearing on the theory of the hardening of steel, about which so much has been heard in recent metallurgical discussions.

Hardening carbon is usually estimated by subtracting the percentages of the other forms of carbon from the total carbon. Consequently, the errors of the other methods appear in the result.

A colorimetric method is given by Jüptner von Jonstorff (*loc. cit.*), of about the same degree of accuracy as in the case of the carbide.

* *Zeitschrift für Anorganische Chemie*, 1896, Vol. XIII.

† *Iron and Steel Institute*, 1893, Vol. II., page 58.

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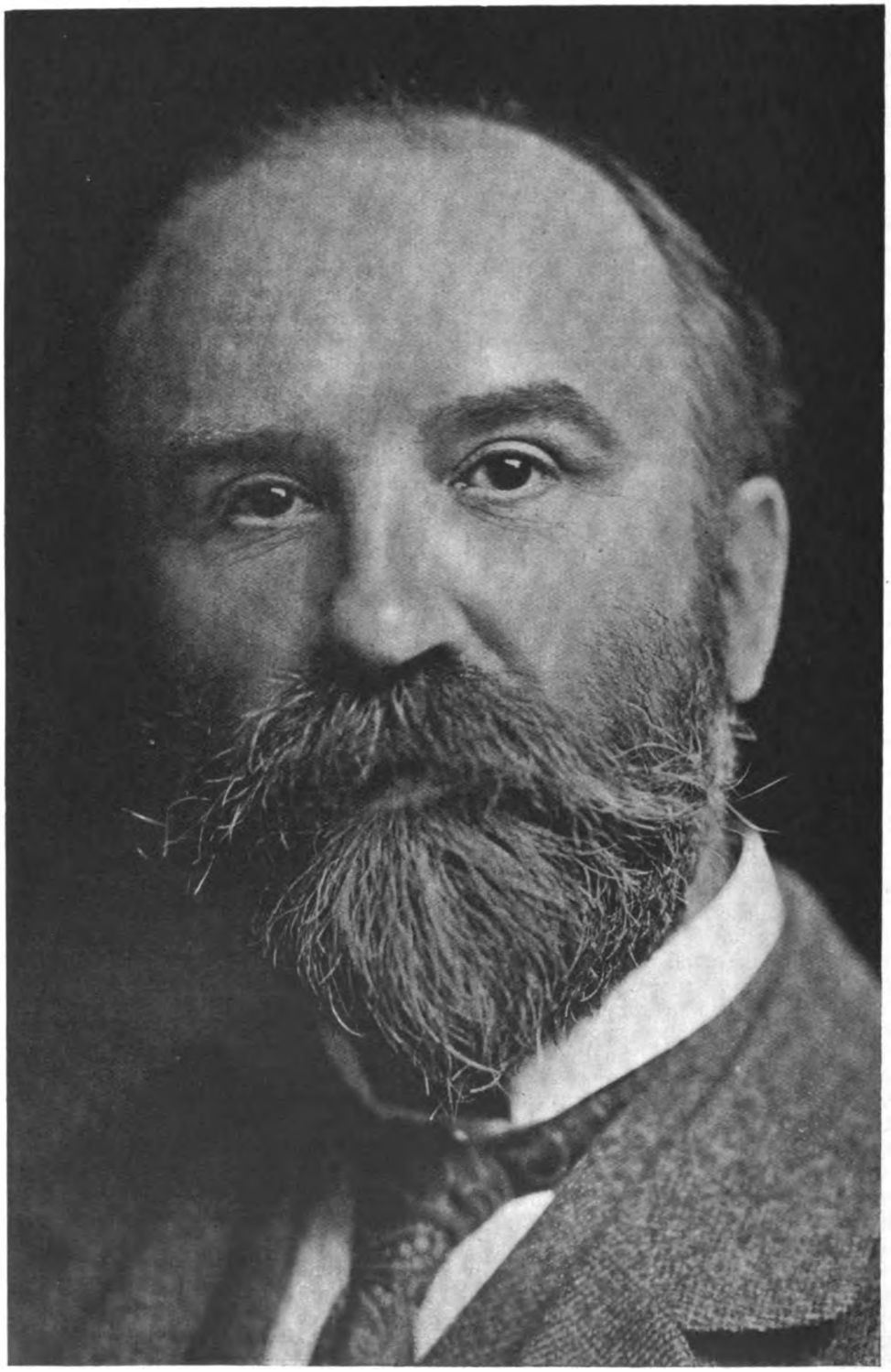

WILFRID J. LINEHAM, M.I.C.E., M.I.M.E., M.I.E.E.

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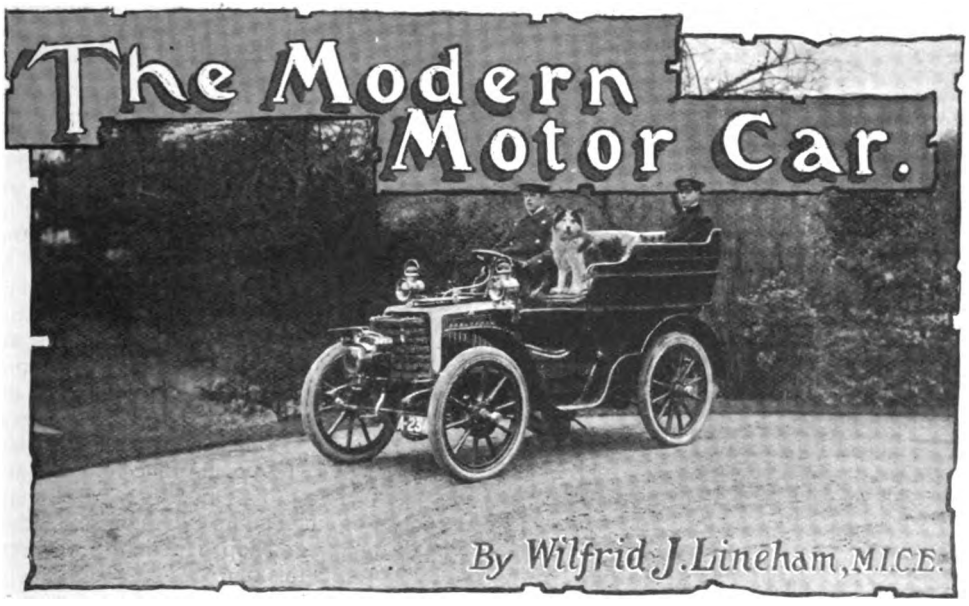

Illustrated with Original Diagrams by the Author.

THE motor industry has indeed acquired gigantic proportions. I wonder what the old promoters of the '51 Exhibition would have thought if they could have seen the Crystal Palace in February, 1904, filled from end to end, and through every transept, with motor cars that even elbowed Pharaoh on one side, as though they would say, "Look here, old chap, you've been on show long enough: it's our turn now." Not less than 120 firms exhibited cars and accessories, which meant 600 cars or other vehicles; and not only were there firms formed specially and solely for motor work, but many of the large old engineering firms, such as Armstrong-Whitworth, Thornycroft, Crossley, and Willans, were seen to have added motor building to their lists, so that it has now become a keen competition between central stations and motor cars as to which will ultimately employ the most workmen. No such *furore* has been known since the early days of the locomotive. Engineers are motor-mad; and when we are told that the motor trade has practically doubled itself within the last year, he would be a bold man that would prognosticate its future. The motor car has a double fascination: it not only attracts the sporting *chauffeur*, who thinks only of how much ground he can cover against time, and desires but little knowledge of the mechanism; but it occupies, with probably much greater sway, the mind of the engineer, keenly intent on divining what may be the fittest design and details to survive.

In spite of the fact that a great deal has been written about motors, the designs have changed so rapidly that much of the matter is behind date. Further, I am quite certain that the general ideas of many people are more hazy than they need be; so I think that a simple account of the present condition of the motor car, from the standpoint of engineering design, will be specially acceptable at this moment.

In the first place, we may note that there are five main uses for motor vehicles: *work*, to take the place of draught horses, to reap, mow, and even plough: *light business*, such as for delivery vans: *runabout*, as for doctors' visits and commercial travellers' calls: *pleasure*, such as touring; and *racing*. Up to the present, the largest use for cars has undoubtedly been for pleasure and runabout; and there is also no doubt that petrol, as a fuel and working substance for internal-combustion engines, has proved the most serviceable, whatever the future may

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bring. This is not to say that steam and electricity may not both have a brilliant future; but as my descriptions are concerned with the "modern car," I shall confine myself to

THE PETROL-DRIVEN PLEASURE CAR,

and endeavour to describe its essential characteristics by the aid of typical examples. The following table will serve to classify such cars:—

Classification of Petrol Cars.

Car.	Carrying.	Engine.	Brake H.P.	Speed per hour.
Voiturettes, or smallest Cars	2 people	1 cylinder (rarely two)	4 to 8	15 miles
Light Voitures, or small Cars	3 to 4 people	2 to 3 cylrs.	5 to 10	20 ,,
Touring and large Cars.	4 to 8 people	4 to 6 cylrs.	12 to 30	30 ,,
Racing Cars.	2 people	4 to 8 cylrs.	30 to 75	70 ,,

Just because the modern motor-car was first introduced from France, a large number of French terms have been applied to its details, and some of these have remained. The upper part is now called the "body" rather than the French "*carrosserie*"; but the lower portion, including the frame and wheels, and all the machinery, has been conveniently termed the "*chassis*," which word has now taken root in our language. I need hardly say, it is with this portion of the car that we are now chiefly concerned. As I have said, the form of car to be described will be determined, so far as possible, by the practice of the majority, with such additional attention as can conveniently be given to important deviations, and a mention, from time to time, of what forms are likely to stay, and what it seems advisable to remove. For it must not be supposed that a popular design at this date is evidence of fit survival; on the contrary, it is very largely a question of fashion. As one maker said to me at the show, "Fashion is responsible for a good deal of what we turn out. We do not always build as we do just because we think it right, but more often because people demand it. Someone wins a race with a car having a live axle, and then nothing but live axles will sell; next year we shall probably be all back to chains again." Another maker said: "I am sure the present engine and shaft are wrongly placed; it is certainly the most sensible thing to put it parallel with the hind axle, and drive by tension elements,"——and so on. Thus, although the motor car has settled down, it is doubtful if finality has been approached.

A very good feature of the recent show was the exhibition, by every firm, of at least one *chassis* with the body removed, so that all ardent enquirers could take their fill of the moving parts; and the first thing to be noticed was the complete absence of belt driving. The extreme inflexibility of the petrol engine drive, and the difficulty of altering the speed by an adjustment of the gaseous mixture within but narrow limits, or indeed by any direct action upon the engine, has made the gear box a necessity; while between the gear box and the engine a frictional connection becomes imperative, so as to secure a *gradual* slip into or out of driving action. Of course, belting, from our old workshop experience, was very attractive for this purpose; but change of weather caused such great trouble on account of extreme variation in grip, and consequent difficulty in hill-climbing, that although experts might patiently stick to belts, ordinary users found such driving so risky that it was finally abandoned. There will always be sufficient troubles of an ordinary kind inherent to petrol motors, without taking in gratuitous ones. The friction clutch between engine and gear, as now adopted, is of the same character as the belt-drive: *viz.*, it is the grip or slip of leather upon metal; but the pressure at full grip is obtained by a resilient spring, and is, therefore, quite constant.

The distinction between live-axle and chain-driven cars was, only a twelve-month back, the distinction between small and large pleasure cars. This difference no longer holds, and the choice of one or the other is now merely a decision as to which is believed to be the lesser evil; for there is no doubt that they both possess drawbacks.

Let us turn to Fig. 1, which shows the older form—that of a chain-driven car with fixed hind axle, upon which the wheels turn loosely. This form is still adopted by some of the best firms, such as Daimler, Napier, and Panhard, who sell their cars at about £1,000 each, and certainly put the most beautiful machine work into them. The chief organs of the car are clearly indicated; but before going further into detail, let us look at Fig. 2, representing the *chassis* of a car with a "live" hind axle—*viz.*, one that turns

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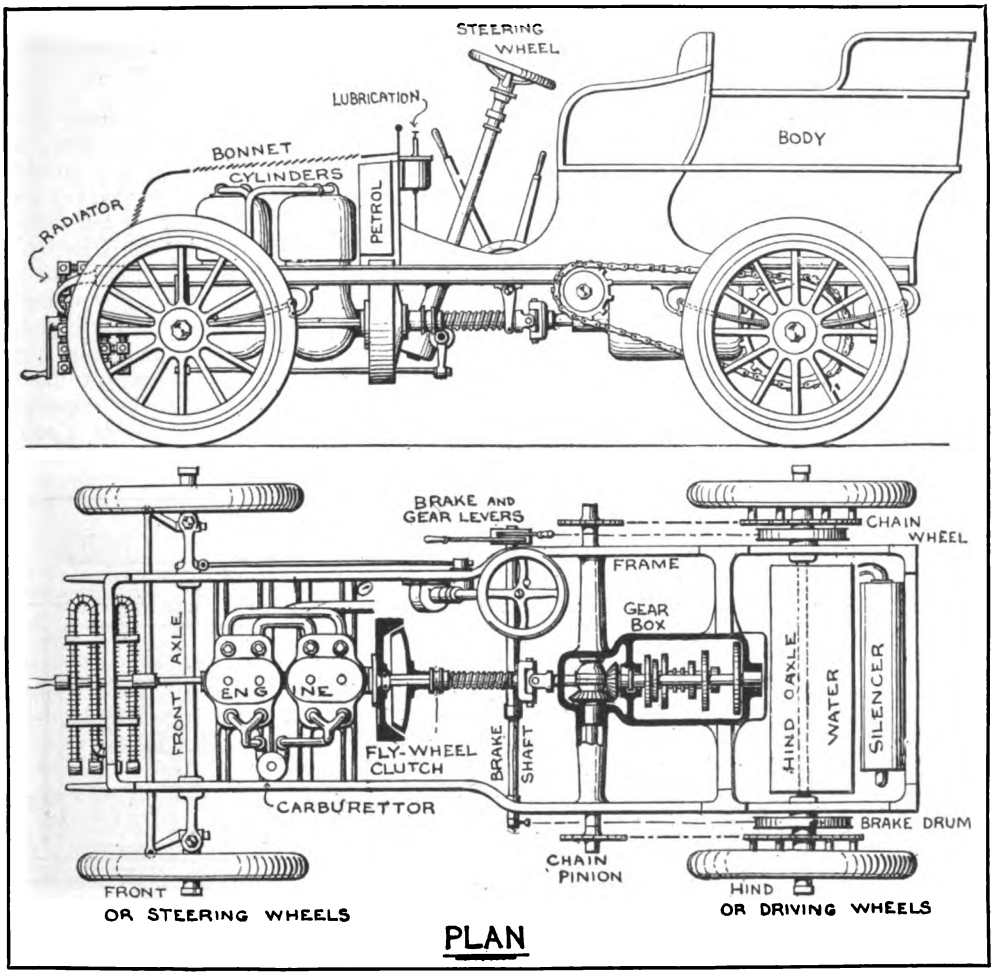

FIG. 1.—A CHAIN-DRIVEN MOTOR CAR.

solidly with the wheels, which is the form now adopted by about 50 per cent. of the manufacturers—and we shall be able to compare the two principal and typical forms. Most cyclists know the difficulties attendant upon the chain, how it stretches, or wears, or both, so that after a time it is impossible to back-pedal with comfort. On the other hand, chains are cheap to renew, and there are some fine samples to be obtained, such as the "Renold," which I shall refer to later. The live axle has one or two universal or Hooke's joints, which wear very considerably, and soon cause "slogger;" though there is less trouble if the joints are thoroughly protected from dust, and are kept well oiled. These joints are required to permit the car to rise and fall upon its springs, and one great advantage of the positive drive has been that the "backing" of the car down hill can be arrested by any of the brakes without shock, which was not always the case with a slack chain. The extra brake on the propeller shaft has largely obviated this difficulty. After all, time alone can decide which of these forms of drive is the better; but it is well to remember that chainless bicycles went out of fashion in favour of chains.

At this stage we may conveniently ask, in order that the subsequent description of details shall become intelligible: "What is a motor car, and of what does its essential mechanism consist?" Firstly, there is now a single rectangular frame which is to carry not only the car body, but also the mechanism; and this frame rests upon the two axles through the medium of springs. The hind

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wheels always run parallel with the frame, upon a fixed or live axle as the case may be; but the front wheels may be slewed to right or left by suitable gear, for the purpose of steering the car. Next comes the petrol engine, of any convenient number of cylinders, according to the power required: a horizontal or "propeller" shaft transmits this power in a longitudinal direction along the centre of the frame, through the intermediary of spur gear, that may be changed in ratio so as to produce the various speeds desired when the car is on the road. The gear box, as already stated, is a necessity in all oil engines that are required to give a greater variation in speed than can be obtained in the engines themselves. After passing the gear-box the speed is still further reduced, either by chain wheels, or by bevel gear to a live axle. Two sets of brakes are now supplied: one upon the longitudinal or propeller shaft, immediately behind the gear-box, varied sometimes by being placed upon the chain shaft; and the other (in duplicate) just within the hind wheels. A friction clutch is also required to allow a gentle change of speed by its slipping, or to entirely disconnect engine and gear—an artifice necessitated by the inelastic character of the engine. This clutch is almost always placed within the fly-wheel. A petrol tank feeds a carburettor that automatically prepares the gaseous mixture for the cylinders. A supply of water to be circulated round about the cylinders, to a radiator or cooler, completes the essentials. With this general statement of the mechanical parts, we may proceed to consider each one in order, commencing with

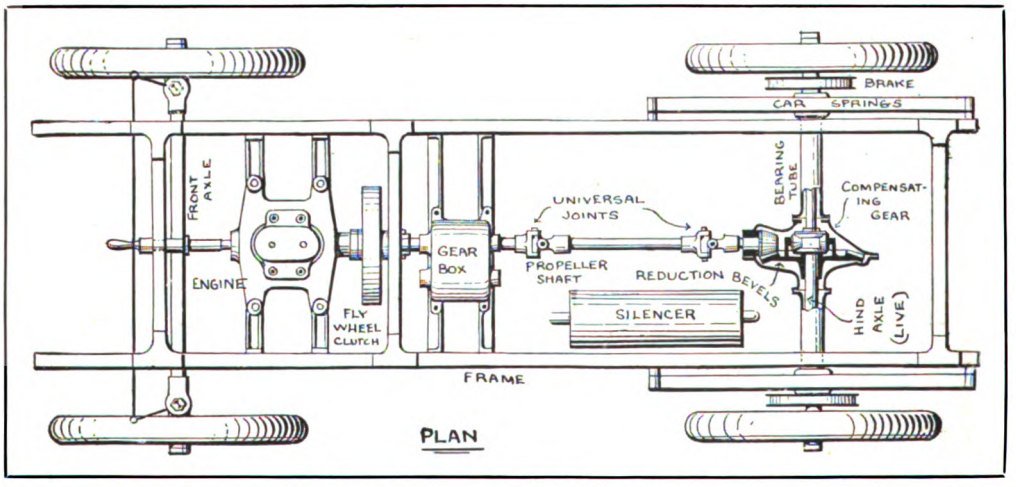

FIG. 2.—A CHAINLESS MOTOR CAR.

THE CYLINDERS.

These have passed through many stages before arriving at their present form; and the fight has been mainly on two grounds: (1) *slow running* v. *quick running*, (2) *single cylinder* v. *multiple cylinders*. I say nothing here of perfect balance, for that ought to go without saying at all times. There are still some makers who adhere to slow running, of whom I may mention the "Oldsmobile" firm. Their engine makes only about 600 revolutions per minute, as against the old Benz at 850, which used to be considered slow, and the Dion type engine at 1,000 to 1,500, or even more. The Oldsmobile (Fig. 3) is certainly a steady running car, having one cylinder arranged horizontally, with long connecting rod; but it is well to consider what one pays for this. Some years ago, Sir David Salomons said that the petrol engine would propel little more than its own *chassis*, and that increase in engine power produced but little additional carrying power. But this was said when slow-running engines were alone in vogue. Let the reader carry his memory back to the giant Willans engine and the still greater giant Borsig at the last Paris Exhibition, both of about 2,500 horse-power; the former, at 300 revolutions, having about one-third of the weight of the latter at 80 revolutions per minute—an object-lesson not to be forgotten. Though not of paramount importance regarding stationary engines, the lesson cannot be

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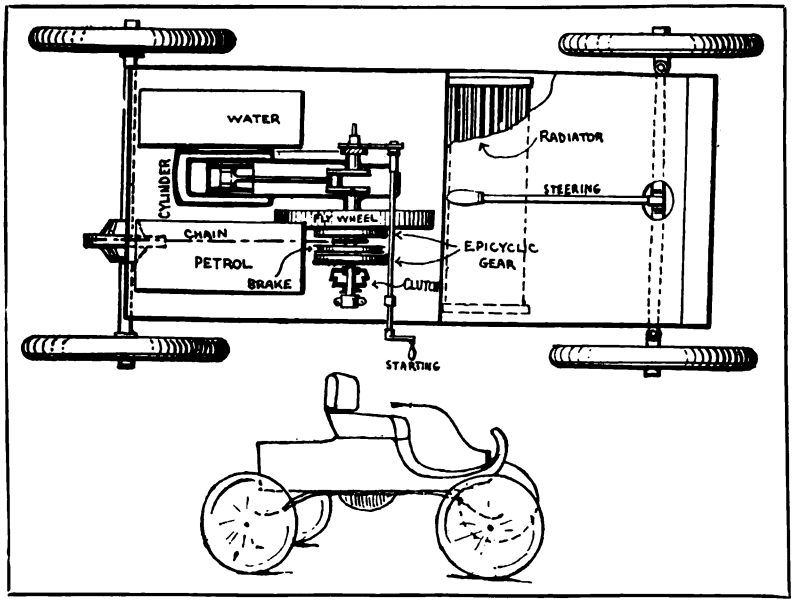

FIG. 3.—THE OLDSMOBILE CAR.

overlooked in connection with motor car engines; and thus we see how engines of the Dion type, at 1,500 revolutions per minute, must naturally be of lighter construction than slow-speed engines. Certainly, high-speed engines are difficult to balance; but they *can* be balanced. So there seems no doubt that the slow-speed engine is doomed.

As to number of cylinders, I may mention that Lieut.-Col. Mark Mayhew, a renowned amateur racer, in answering a question of mine some years ago, said that he preferred as many cylinders as possible; and time has shown him to be right, even though many makers have stuck to the single cylinder pretty tenaciously, through fear of not synchronising the explosions. This year we see the Wilson-Pilcher car of Armstrong-Whitworth and Co., having *six cylinders* with opposed pistons; while Binks, of Nottingham, exhibits a bicycle of four cylinders, totalling 5 horse-power (Fig. 4). A few cheap voiturettes are made with a single cylinder—merely, I was told, on account of low price, and because a single cylinder was "good enough to learn on." I fear, however, that beginners would be more likely to be deterred for all time by the excessive shock occasioned when such an engine begins to misfire; and anyone who has studied engine balance knows that it is impossible to avoid vibration where reciprocating parts are only opposed by revolving weights; for side shocks are thereby caused. I feel certain that another year will see the complete elimination of single cylinders, in cars of all prices and sizes.

The De Dion two-cylinder engine of 10 horse-power is shown in Fig. 5, each piston having a diameter of $3\frac{1}{2}$ inches, and a stroke of $4\frac{3}{8}$ inches; the average speed being 1,200 revolutions per minute. The exhaust valve is opened every other revolution by the lift of a revolving cam, which is on the usual lay shaft rotating at half the crank speed; while the inlet valve, as shown, opens by suction. A noteworthy point is the supply of oil from a small pump by channels through the crank shaft and connecting rod to the piston; the more common dash lubrication being dispensed with. The cranks are directly opposed, as are of course the pistons; but there is an unbalanced moment due to the reciprocating parts not being in direct line; in fact, the best results can only be obtained with two cylinders, when the pistons are at the same time opposed and in line, as in Fig. 6. Till recently it has been an article of belief that cylinders should be arranged in even numbers,

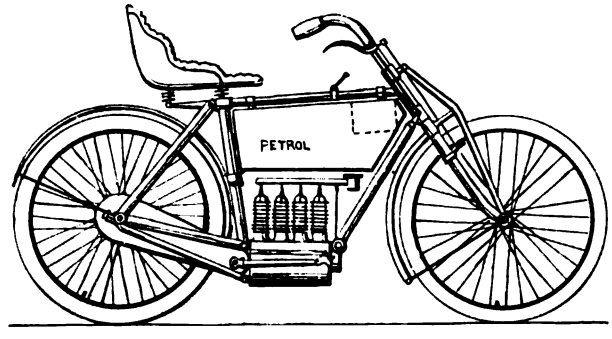

FIG. 4.—BINKS'S 5-H.P. FOUR-CYLINDER BICYCLE

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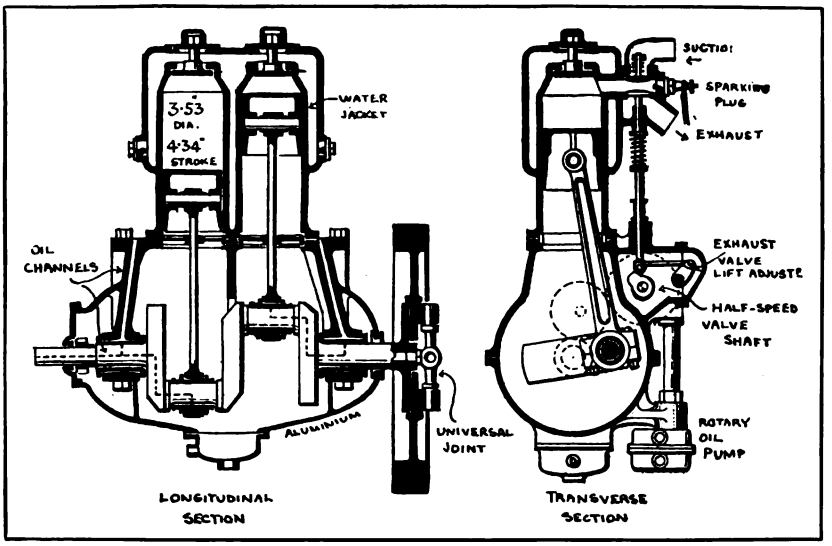

FIG. 5.—THE 10-H.P. TWO-CYLINDER DE DION ENGINE.

such as 2, 4, or 6, so that the explosions might be balanced; but three-cylinder engines have now been introduced with excellent results. This is the smallest number of side-by-side cylinders that will procure balance of masses, while not, however, completely balancing the explosions; but the latter fault is said to be imperceptible in practice, the result being essentially as good as in a four-cylinder engine, while the "torque," or turning effect, is even more regular. There are still some critics who fear trouble with three cylinders, should one misfire; but the obvious answer is, that sparking and carburation must be perfected to an extent that will render misfire impossible. The Cottereau engine in Fig. 7 serves to illustrate this kind of engine, and also shows the modern mechanically lifted valves for inlet as well as exhaust. To this end there are two lay or half-time shafts, each provided with a cam to lift the valve spindle, and a spring for re-closing; the setting being such that the well-known Otto cycle of operations is performed, having suction, compression, expansion, and exhaust for successive strokes; the ignition occurring between compression and expansion. The cranks are set at thirds, or 120°, as also are the explosions; and the pistons have each $3\frac{1}{4}$ inches diameter, and $4\frac{1}{4}$ inches stroke, the whole engine developing 16 horse-power at 1,200 revolutions per minute. Of course it is a simple matter to modify these designs for four or six cylinders, when a curious fact is observed; *viz.*, that a larger number of cylinders gives greater starting ease, as evidenced by Binks's bicycle (Fig. 4), which only needs wheeling for about a yard to take up its full work. Lastly, it may be mentioned that if there should remain some masses that are incompletely balanced, the cylinders are best set horizontally, and preferably *across* the frame: the unpleasant upward bounce due to resonance of engine and car vibration being thereby avoided.

As everyone knows, there are essential differences between engines using steam, and those using hydro-carbon gas as a working substance, not the least important of which is the effect of leakage. A steam engine will permit the loss of even 30 per cent. of its steam through leakage, and all we perceive is the high coal bill; but much lower leakage

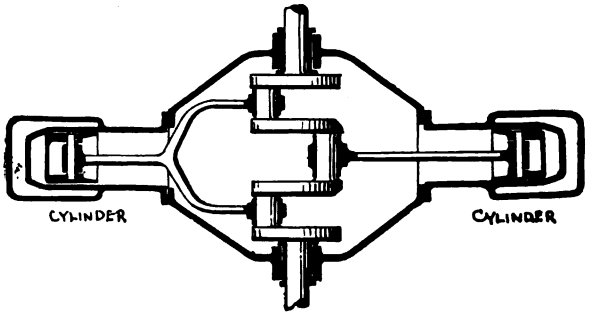

FIG. 6.—A TWO-CYLINDER BALANCED ENGINE: ILLUSTRATING THE PRINCIPLE OF OPPOSED PISTONS.

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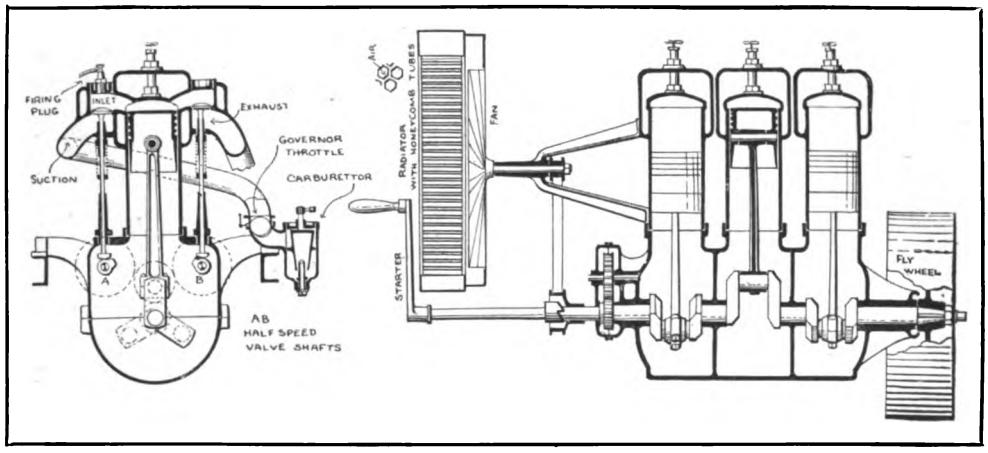

FIG. 7.—THE "COTTEREAU" 16-H.P. THREE-CYLINDER ENGINE.

in oil engines results in a dead stop. It is, then, absolutely necessary to keep valves and piston rings thoroughly tight, or the horse-power will go down till the engine entirely refuses to work. Valves are the chief trouble, so they are now made easily removable, as in Fig. 7; re-grinding is easily accomplished, which is important, for a fully-worked car may require re-grinding of valves every few weeks.

THE CARBURETTOR

is the small vessel in which the petrol vapour and air are mixed in suitable proportions, and is a necessary adjunct to all oil motors. Past examples have been known as "surface-feed," "spray-feed," and "positive-feed" carburettors. The first is now non-existent, on account of its uncertainty; in it, air was merely passed over a surface of petrol. The third has only been partially successful, but cannot be said to hold the market. The spray-feed apparatus is therefore typical, and is well illustrated by the Dion-Bouton carburettor of Fig. 8, in which there are many good points. The petrol tank, situate on the dashboard (see Fig. 1), is connected to the carburettor at A, and the fluid rises, when so permitted by the needle valve, into the float chamber B. The float rests at first upon the levers that lift the needle; but as petrol enters and raises the float the needle falls, and either cuts off or diminishes the petrol supply. Thus the petrol is automatically kept at a constant level in the chamber, *viz.*, at the same height as the central nipple, from which it exudes like dew. Air enters at C, by the suction of the engine piston, and passes out at D mixed with petrol gas, on its way to the cylinder; the action of the charging stroke having caused the petrol dew to be continually drawn off by the air. The level of the petrol can be adjusted by altering the needle length; and the fact that float and nipple are concentric in plan view prevents inclination of liquid affecting the amount of exuded petrol. As a heavy pull from the engine vaporises more petrol, it is necessary to provide a supply of extra or adjusting air to keep a constant richness of the mixture. This is accomplished by the valve or sleeve E. When this is moved in one direction, the opening at C is reduced; when moved in the opposite direction, extra air can be bye-passed from C to D without meeting the nipple, and the two air-streams produce the desired result.

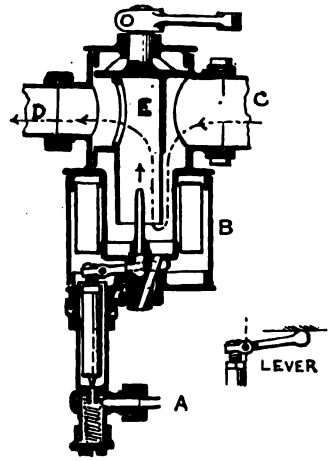

FIG. 8.—THE DE DION-BOUTON CARBURETTOR.

I may here describe the beautiful automatic carburettor just introduced by Messrs. Crossley. Referring to Fig. 9, there are three views, the meaning of which is clearly explained on the diagram. Petrol enters the float chamber E, where it is kept at such a level as to just ooze out at the nipple F, its outlet being further

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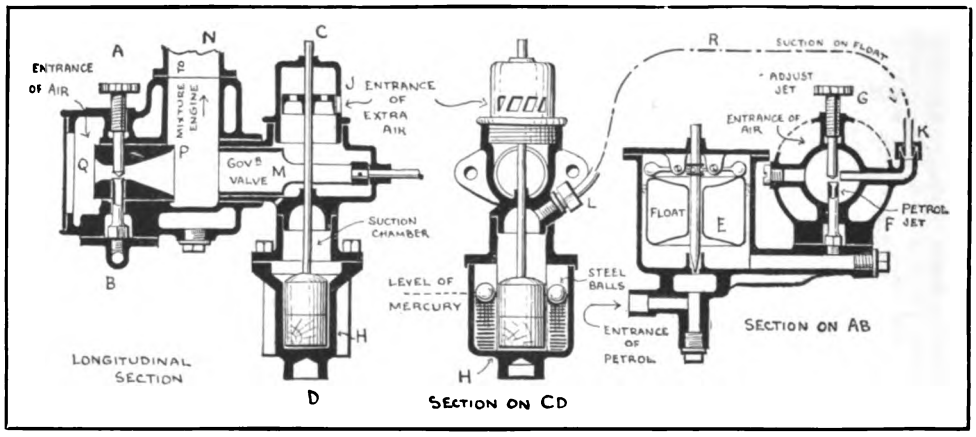

FIG. 9.—CROSSLEY'S CARBURETTOR.

regulated by the hand screw G. A wooden float H dips into mercury in the chamber D, and carries, by a vertical rod, the piston valve J controlling the admission of the extra or adjusting air. A pipe connects the second nipple K with the opening L, just over the wooden float; and the tubular valve M, operated from a governor, acts as a throttle on the prepared mixture on its way to the engine. When the carburettor is in action, the petrol is drawn from Q to P past the spray nipple, by air entering through gauze gratings; but if the suction be excessive, a partial vacuum is produced immediately over the float H by means of the suction through pipe KL, and the piston valve J automatically admits the larger amount of extra air which is needed to adjust the greater vaporisation of petrol, so that a mixture of constant richness results. The mercury is steadied by steel balls, and kept from oxidation by a film of glycerine. A personal trial of the suction assured me of the extreme sensitiveness of the piston valve.

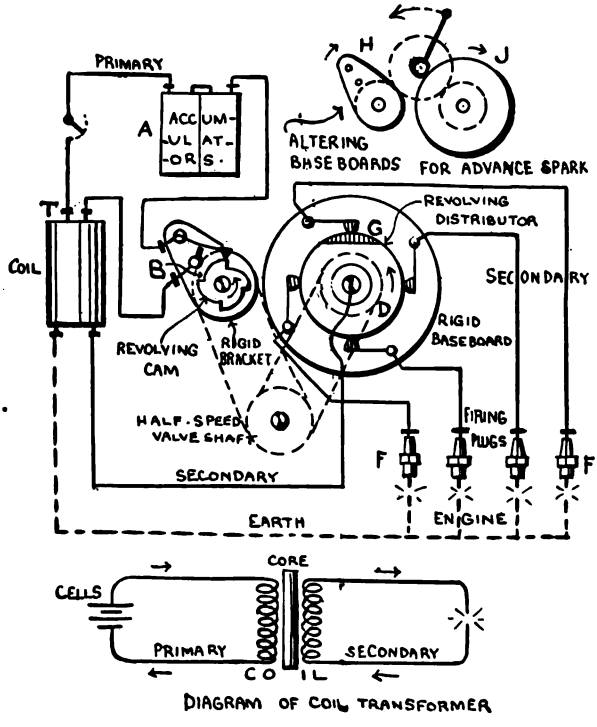

FIG. 10.—WIRING ON HIGH-TENSION ACCUMULATOR SYSTEM.

THE FIRING OR IGNITION

of the charge is now always performed electrically. The story of electric ignition in internal-combustion engines is a long one, and is a record of much failure, extending from 1867 to the present day. But inventive success is almost always assured when there is a legion of workers in the field; added to which the danger of hot tube and lamp on motor cars proved an immense stimulus in the perfecting of the spark. As a result, the early verdict against electric ignition has been completely reversed, and we have to acknowledge that there is now much trustworthy apparatus on the market. At the present moment the systems resolve themselves into (1) high-tension current from accumulators or magneto-machine; (2) low-tension current from magneto-

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machine. Dry primary cells have entirely vanished before accumulators; neither do I see any examples of direct dynamo ignition.

The accumulator system, as applied to a four-cylinder engine, is shown in Fig. 10. An induction coil, having a trembling hammer at T, comprises the usual soft iron-wire core, round which the thick primary wire is coiled. Over this again, but insulated therefrom, is the coil of thin secondary wire. The trembler, in the primary circuit, makes and breaks rapidly on account of the change in magnetism of the core. The trip (or interrupting) cam B, and the distributor D, in primary and secondary circuits respectively, are both rotated at the same speed as the valve shaft by chains or wheels. Four times in a revolution of this shaft (but depending on number of cylinders) does cam B break the primary circuit, and thus induce a highly intensified current through the secondary wire that leads to the firing plugs F F; but the distributor intervening, such current is only allowed to spark in the particular cylinder to which it is led by the brushes or wipers on G. It is customary to fire in the order 1, 3, 2, 4 of the cylinders; that is, to take opposite cranks in pairs. The supporting plates H and J (in the upper figure) may be rotated equally through a small angle, so as to alter the times of contact and cause the spark to be formed at varying positions of the engine stroke, with a corresponding variation in power, the method being known as that of "advance spark." Thus the mixture is ignited at about half expansion stroke when starting, the compression being then low and the power obtained the smallest; after which

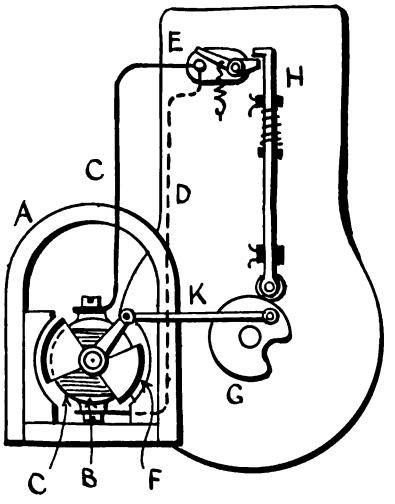

FIG. 11.—THE SIMS-BOSCH MAGNETO FIRING SYSTEM.

the spark is gradually altered to the beginning of the stroke where compression is highest, and a greater power may therefore be developed. This ingenious contrivance will alter the engine speed between pretty considerable limits.

The lower portion of Fig. 10 is introduced to show more clearly the arrangement of primary and secondary wires, coil, and battery; dotted lines show "earth" in the main figure, or where the secondary current returns through the frame of the car. The accumulators A are arranged in pairs, and consist of lead plates, made generally as grids, of which the spaces are filled with red lead and dilute sulphuric acid for the positive plate, and litharge and dilute acid for the negative plates. The electrolyte or liquid in the cell is also dilute acid, and is often, for convenience, mixed with some form of jelly. I noticed some firms made the electrolyte of a paste of sulphate of lead and acid, with the object of preventing sulphating of plates at low charges, which they assured me was prevented. I confess, however, to a rooted objection to any paste or jelly in

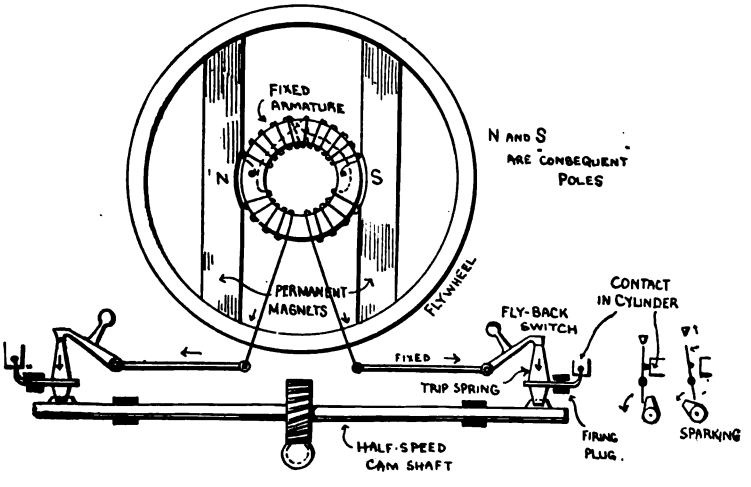

FIG. 12.—THE LANCHESTER MAGNETO FIRING SYSTEM.

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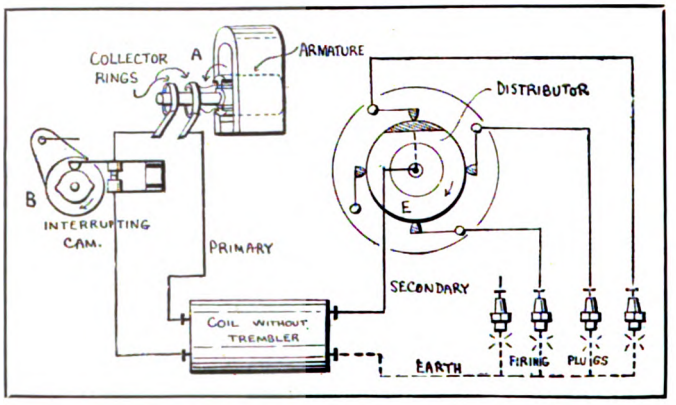

FIG. 13.—THE EISEMANN HIGH-TENSION MAGNETO SYSTEM.

accumulators, and found my objection supported by the French firms. The easiest way of charging cells is to use an ordinary electric lighting circuit; convenient charging boards may now be purchased.

Low-tension magneto-ignition is used in the Sims-Bosch machine (Fig. 11.) A is a permanent magnet, and B a fixed armature, of wnich the wires make circuit with the firing plug. F is a soft iron shield rocked by the rod K. As the cam G rotates, it permits the tappet H to fall at the proper time, pull the trip lever, and break circuit at E, causing a spark. It is arranged that the shield shall rock at highest speed at the moment of rupture.

A very excellent form of low-tension magneto-ignition is that used in the Lanchester engine, and illustrated in Fig. 12. Mr. Lanchester puts his permanent magnets on the fly-wheel, where weight is needed, and "consequent poles" are produced at N and S on account of the continuity of the force lines through the fly-wheel rim. These magnets, rotating round a fixed armature, cause a current to pass through the wires, trip spring, and cam shaft. The arbor of the trip spring passes into the cylinder through the firing plug (Fig. 15) to a platinum point, and the action of the rotating cam is to press

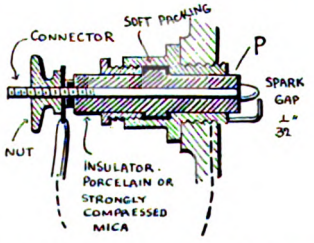

FIG. 14.—THE COMMON TYPE OF SPARKING PLUG.

this point down on its bed. When the cam passes the trip, the latter, being released, sharply releases the platinum point and throws back the flying switch, thus causing the whole of the current to suddenly jump the point and give a "fat" spark. This takes place, of course, in each cylinder alternately.

The Eisemann system was introduced only last year, but bids fair to take an important place. Because of the easy leakage of high-tension current, magneto machines were introduced; these, in turn, often fail through the very weakness of the current. The new system, therefore, while adopting the less troublesome magnets, intensifies the current to an *intermediate* pressure, so as to steer between extremes. Fig. 13 is an arrangement applied to four cylinders. The machine A has fixed magnets and a rotating armature, but no commutator. Instead there are two simple collecting rings completing the primary circuit; and as the current is already alternating, there is no need for a trembler on the coil. The distributor is placed in the secondary circuit as previously described, and the spark is caused by short-circuiting the current at B, instead of breaking the circuit. So far as I could see, the results seemed excellent.

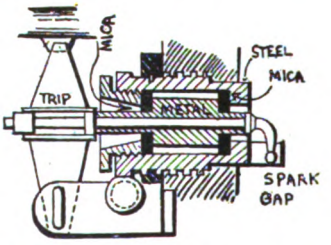

FIG. 15.—THE LANCHESTER PLUG.

As to firing plugs, Fig. 14 shows the common form. This has been extensively used, but the porcelain P is apt to break or crack, and a high-tension current easily "shorts" or escapes. The present tendency is to make plugs larger in diameter, and to insulate them with discs of mica that, of course, stand vibration. The only objection to mica is the leakage of current if moisture intervenes between the layers; but this may be obviated by heavily compressing the

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material beforehand into a solid block that can be afterwards held in place by screwed brushes. The Lanchester plug (Fig. 15) will sufficiently illustrate my meaning, where all is metal except the insulating discs. As already explained, the current always passes through the centre of the plug, and returns by the engine body.

I must not omit to mention the external spark gap that is now universally employed, and which I may call the "Panhard" spark gap. Whether true or not, it is said that some of Panhard's workmen discovered accidentally that an *external* gap of $\frac{1}{32}$ inch, in addition to that within the cylinder, made the internal spark occur with greater certainty. The truth of the result itself is indubitable, so that the secondary wire is now led to the dashboard and there interrupted by a suitably protected contrivance, when the driver can see if the sparking occurs regularly.

(*To be continued.*)

VECTORS AND GRAPHS AND THEIR PRACTICAL APPLICATION.

PART II.

By ELLIS H. CRAPPER, M.I.E.E.

PROBLEM II.

To determine the sum of any number of vectors.

THE parallelogram-law method of compounding two vectors may be extended to the summation or addition of any number of concurrent vectors. It follows from first principles that if we compound the first vector with the second, and then the resultant of these with the third vector, and so on, the final resultant is the required vector sum. This is the principle by means of which the resultant vector, $\overline{OS}$, of the three vectors $\overline{OQ}$, $\overline{OP}$ and $\overline{OR}$ has been obtained in Fig. 1, 1, the separate processes being indicated by the different types of dotted lines. It is better, however, in finding the vector sum of a number of vectors greater than two, to use the method of the *polygon of vectors*.

Thus, in finding the vector sum of the three vectors $\overline{OQ}$, $\overline{OP}$ and $\overline{OR}$ (Fig. 1, 1) by this method, draw the vector $\overline{QP^1}$, equal to the vector OP (Fig. 1, 2) from the end Q of the vector $\overline{OQ}$, and from P^1 draw the vector $\overline{P^1R^1}$ equal to the vector OR; then by joining the points O and R^1 by the line OR^1, the closed polygon OQ P^1 R^1 O is formed, and $\overline{OR^1}$ is the vector sum of the component vectors $\overline{OQ}$, $\overline{QP^1}$ and $\overline{P^1R^1}$, in magnitude, direction, and sense. For by obtaining the projections of $\overline{OQ}$, $\overline{OP}$, OR, $\overline{QP^1}$, $\overline{P^1R^1}$, and $\overline{OR^1}$, upon the axis Oy it will be found that

$$Or^1 = Oq + qp^1 + p^1r^1$$
$$= Oq + Op + Or;$$

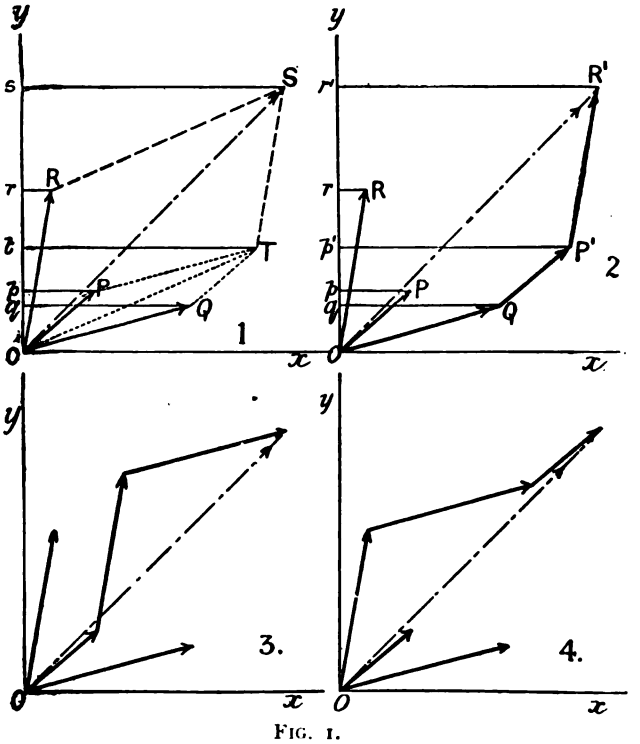

FIG. 1.

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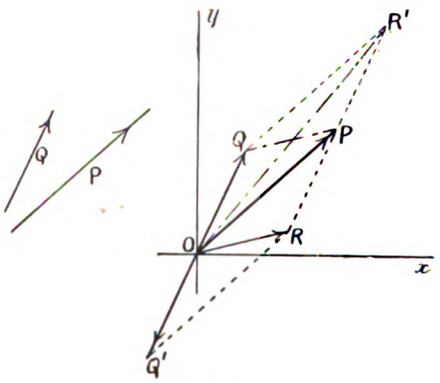

FIG. 2.

that is, Or^1 is the projection of a vector $\overline{OR^1}$, and is equal to the sum of the projections of the three vectors $\overline{OQ}$, $\overline{OP}$, and $\overline{OR}$, therefore

$$\overline{OR^1} = \overline{OQ} + \overline{OP} + \overline{OR}$$

It will also be found that $\overline{OR^1}$ (Fig. 1, **2**) is equal to $\overline{OS}$ (Fig. 1, **1**) It may here be remarked that the order of addition is indifferent, as shown by the two additional figures (Fig. 1, **3** and **4**) the result obtained by each being the same. Now, it is obvious that if a vector $\overline{R^1O}$ or $-\overline{OR^1}$ be added to the three vectors $\overline{OQ}$, $\overline{OP}$, $\overline{OR}$, the vector sum will be zero, because $\overline{OR^1} + \overline{R^1O} = 0$; in other words, the vector $\overline{OR^1}$ is the *resultant* or *equilibrant* of the three vectors $\overline{OP}$, $\overline{OQ}$, and $\overline{OR}$, and it is clear that the figure, which would be formed by the four vectors $\overline{OQ}$, $\overline{OP}$, $\overline{OR}$, and $\overline{R^1O}$ arranged in a circuital manner, is a closed polygon.

Corollary 1. The sum of any number of vectors arranged in a circuital manner, so as to form a closed polygon, is zero.

Corollary 2. If n vectors be represented in direction, sense and magnitude in a circuital manner by n sides of a polygon of $(n + 1)$ sides, the side (with an opposed circuital arrow-head attached) required to close the polygon is the vector sum of the n vectors.

PROBLEM III.

To determine the difference between two vectors.

This is an instance of *vector subtraction*, in which it is required to find the *equilibrant* or resultant of $\mathbf{P} - \mathbf{Q}$, $\mathbf{P}$ and $\mathbf{Q}$ being two vectors, as given in Fig. 2. As before, let $\overline{OP}$ and $\overline{OQ}$ denote the two vectors $\mathbf{P}$ and $\mathbf{Q}$, then if we draw $\overline{OQ^1}$ equal and opposite to $\overline{OQ}$, $\overline{OQ^1}$ denotes the vector $-\mathbf{Q}$. By completing the parallelogram OP RQ^1 we obtain OR, the diagonal of the parallelogram OP RQ^1, which is the required resultant or vector sum of OP and $\overline{OQ^1}$. Obviously

$$\overline{OR} = \overline{OP} + \overline{OQ^1} = \overline{OP} + [-\overline{OQ}] = \mathbf{P} - \mathbf{Q}$$

The same result is obtained by considering $\overline{OP}$ to be the vector sum of $\overline{OQ}$, and the vector required, *i.e.* $\overline{OR}$; for by joining the points P and Q the vectors OQ and QP may be considered as the component vectors of the vector $\overline{OP}$, since they form two adjacent sides of the parallelogram OQ PR, and QP = OR.

If the vector sum of $\mathbf{P}$ and $\mathbf{Q}$, or $\mathbf{P} + \mathbf{Q}$, were required, this would be given by the diagonal $\overline{OR^1}$ of the parallelogram OP R^1 Q, and it is useful to note that the other diagonal of the same parallelogram gives the vector difference $\mathbf{P} - \mathbf{Q}$.

So far the directions of the component vectors have been given in the figures, but the actual positions may very readily be given by means of a *vector equation*. Thus, in the example given by Fig. 1, **1**, if the vectors $\overline{OQ}$, $\overline{OP}$, $\overline{OR}$ and $\overline{OS}$, make respectively the following angles with the horizontal axis Ox, 15°, 40°, 80° and 45°, the vector equation would be

$$\mathbf{S}_{45^\circ} = \mathbf{Q}_{15^\circ} + \mathbf{P}_{40^\circ} + \mathbf{R}_{80^\circ}.$$

PROBLEM IV.

To resolve a vector into two component vectors along two arbitrarily chosen axes of reference.

(*a*) Let the axes of reference make any angle ϕ between them, as shown in Fig. 3, **1**, and let $\overline{OP}$ or $\mathbf{p}$ be the vector. Through the

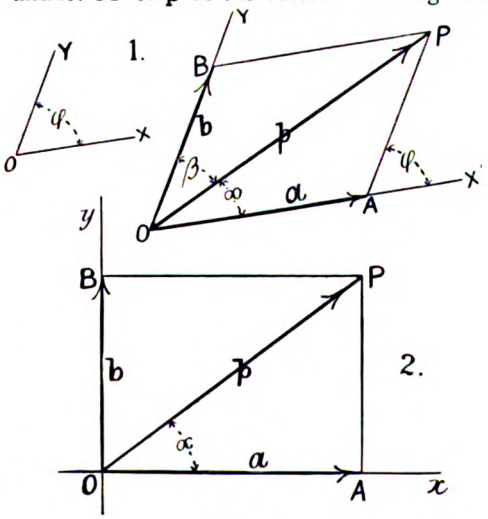

FIG 3.

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extremities O and P of the given vector draw OA and PB parallel to OX, and OB and PA parallel to OY. Then $\overline{OP}$ is a vector which is equivalent to the two vectors $\overline{OA}$ and $\overline{OB}$, therefore $\overline{OA}$ and $\overline{OB}$, or **a** and **b**, are the component vectors of $\overline{OP}$ or **p**, along the axes of reference which make an angle ϕ between them, and

$$\mathbf{p} = \mathbf{a} + \mathbf{b}.$$

The magnitudes of these component vectors may be found by means of the formulæ :

$$a = p \frac{\sin \beta}{\sin \phi}$$

$$b = p \frac{\sin \alpha}{\sin \phi}$$

(*b*) For ordinary purposes, however, it is more usual to deal only with the rectangular components of a vector, that is, when $\phi = \frac{\pi}{2}$ or 90°, and the axes of reference are then mutually perpendicular. Thus, in Fig. 3, **2**, $\overline{OA}$ and OB, or **a** and **b**, obtained by the projection of the given vector $\overline{OP}$ on the two axes of reference, are the rectangular components of the vector $\overline{OP}$ or **p**, the magnitudes of which are given by

$$a = p \cos \alpha.$$

$$b = p \cos (90° - \alpha) = p \sin \alpha.$$

Application. (1.) Four forces of magnitudes 40, 50, 75, and 100 units each act at a point, and their directions, relatively to the horizontal axis, are given as 0°, 30°, 45°, and 150°; it is required to find the magnitudes of two forces which, acting in directions at 20° and 120°, will balance the system.

In problems of this class it will probably be the best plan to determine the resultant of the given forces, which is really the determination of R and θ of the vector equation.

$$\overline{\mathbf{R}}_\theta = \mathbf{p}_{0°} + \mathbf{q}_{30°} + \mathbf{r}_{45°} + \mathbf{s}_{150°}$$
$$= 40_{0°} + 50_{30°} + 75_{45°} + 100_{150°}$$

The vectors representing the forces are shown in Fig. 4, **1**, and the polygon of vectors gives, in Fig. 4, **2**, the resultant as $\overline{OR}$, the magnitude of which is 140 units, and $\theta = 70°$. Consequently a force equal to $-\overline{OR}$ or $\overline{OR^1}$ will just balance the four forces. In other words, a force of 140 units, making an angle of (180° + 70°) or 250°, will balance the four forces. To determine the magnitudes of the two forces acting in directions at 20° and 120° apply the method of resolving a vector into two component vectors along two given axes of reference, so that the required forces will be given by the resolved components of $\overline{OR^1}$ along these directions. In Fig. 4, **2** these are given as $\overline{OP}$ and $\overline{OQ}$, which will be found to be 110 and 102 units respectively.

Examples to be worked.—(1) A vector of length $8\sqrt{2}$ units makes angles of 45° with each of two axes at right angles to each other. Determine the magnitude of the components along each axis. If the same vector makes an angle of 60° with one of the axes, find the magnitude of the component along each axis.

(2) It is required to resolve a given vector into two component vectors at right angles to each other, such that one component is half the other. Determine the angle which each makes with the vector.

(3) Solve the equation

$$\mathbf{R}_\theta = 16_{30°} - 20_{45°} + 30_{60°}.$$

(4) Prove that

$$50_{90°} + 50_{180°} + 50_{270°} = 50_{180°}.$$

(To be continued.)

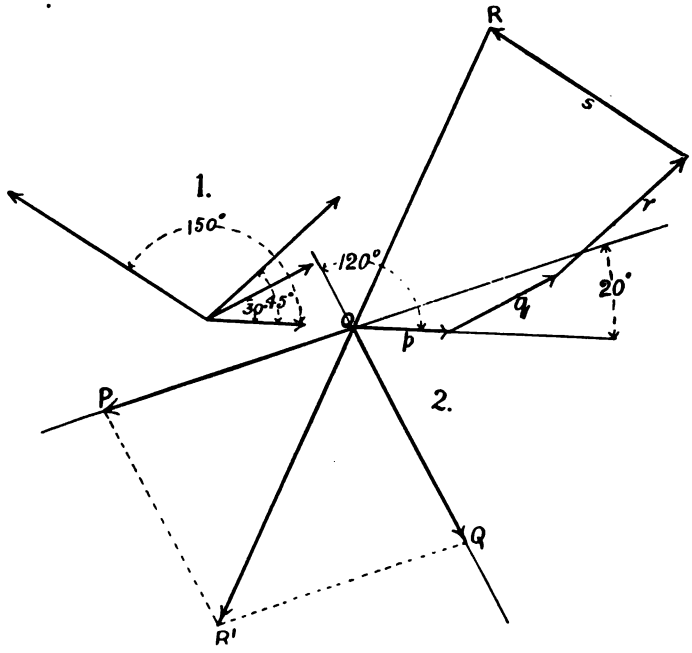

FIG. 4.

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PLANNING, SETTING-OUT AND MAKING STAIRCASES.

PART II.

By HENRY JARVIS.

WE may now proceed with the setting-out and making of a straight flight of stairs, to suit the plan and elevation shown in Figures 10 and 11, which are drawn to scale.

As "going," we have the distance 6 ft. 6 in., between the bottom landing, A, and the upper landing, B; and as height we have the distance, 8 ft. 9 in., from the ground floor line, C, to the first floor line, D. The height should be taken on the rod E, which must then be divided into equal parts. As drawn, it shows fourteen risers, 7½ in. each.

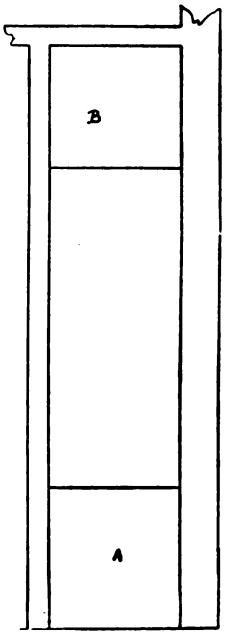

FIG. 10.—PLAN OF STAIR OPENING, WITH LANDINGS.

The rod for the "going" is shown at F. This, as previously explained, must be divided into one part less than the number of divisions in the height rod. Thus we require thirteen parts of 6 in each. We must now make the "step" or "pitch" board (Fig. 12). The board C (which must be 11 in. wide by half an inch thick) is planed up smoothly and one edge straightened. The two lines H and I must then be drawn at an angle of 45 degrees with the edge of the board, so that they form a right angle one with the other. Now on H set off 6 in. from the angle, and on I set off 7½ in. Connect these two points, as shown, and then draw the line K parallel to them. This constitutes the pitch board, as shown by the grained portion of Fig. 12. All the rest must be cut away, and the edges planed square.

For convenience in using, a strip of wood, about 1½ in. wide, is screwed to the straight edge of the board, so that, when finished, it has the appearance represented in Fig. 13.

The application of the pitch board in setting out the string boards is shown in Fig. 14. Both boards should be set out at once, laying them with the face edges outwards, and commencing at the bottom with the going part of the pitch board, which marks the floor line L (this, however, should be left half an inch longer for scribing down when fixing), and then proceeding along the boards toward the top end, repeating from angle to angle until the required number of steps has been set out. It is necessary to leave enough length at the top ends to fit to the skirting, as will be explained subsequently.

All the lines drawn direct from the pitch board must be cut with knife or chisel; for those which come after, a pencil may be used.

The treads and risers must be cut off to the length required, allowing half an inch to house into each string. Thus, with the stairs opening 2 ft. 9 in. wide, as in Fig. 10, and with 1¼ in. strings, each step will have to be 2 ft. 7 in. long, which will allow half an inch to spare in the width of the finished stairs, thus enabling us to get them in easily.

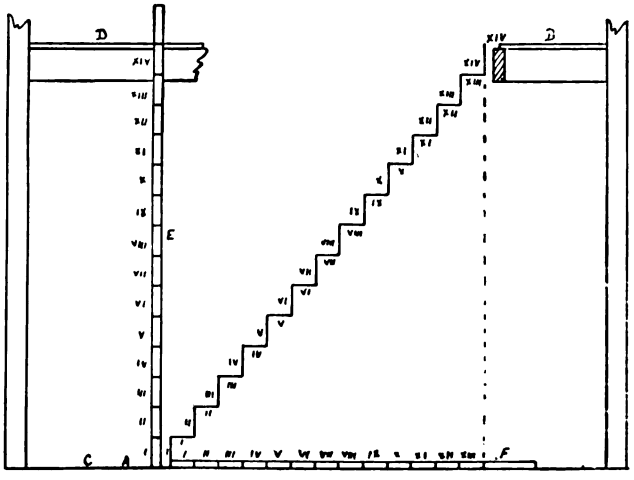

FIG. 11.—SECTIONAL ELEVATION OF FIG. 10.

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The treads (thirteen in number) must be planed up on one side, gauged to a thickness at the front edge and back about 3 in. on the underside, so as to clear the riser; they must also be gauged to a parallel width of

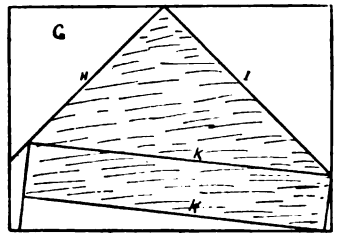

FIG. 12.—STEP BOARD SET OUT.

7 in. The front edges must be rounded to form the nosings.

The risers (fourteen in number) require planing on one side and one edge, and must also be gauged roughly to a width of $7\frac{1}{2}$ in.

The above are now ready for fitting to the strings. To do this, lay the two strings on the bench, face edges outwards, as in Fig. 15, and commencing at the bottom ends, mark

The housing in which the nosing of the landing is to fit should be made with the others, taking care to cut it small enough to ensure a tight fit.

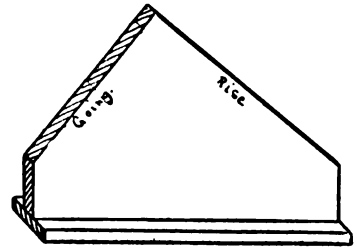

FIG. 13.—STEP BOARD CUT TO SHAPE AND FINISHED.

To put the stairs together, lay one string on the bench with the face edge towards you. Place the whole of the treads and risers in their respective housings, and then lay the other string on them, guiding them into their places, and driving them home with a heavy hammer. When all are driven home, but not before, fix them by nailing through the holes already made, after which

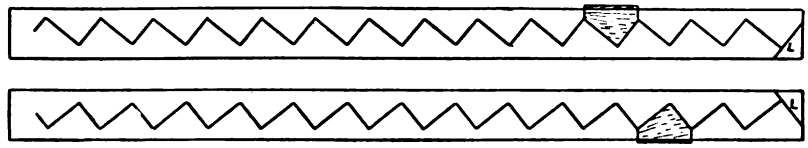

FIG. 14.—SETTING OUT STRINGS WITH STEP BOARD.

the exact position of each riser and each tread, numbering each as we go. After the first riser, the treads must be marked first, keeping the back edges at the angle of the two cut marks, as M, Fig. 15. The risers must be placed as at N, with the top edge level with the mark showing the under side of the tread.

The marks round the nosings should be made with a fine bradawl or marking point. The numbering is best done as shown in Fig. 15 (I. II.), the risers and treads being marked on the back and under side.

After all are marked in and numbered, the housings are bored out with centre-bit, as in Fig. 16, and finished with mallet and chisel. When finished, they will appear as Fig. 17. It is of great importance that all the housings should be of equal depth, and this is best ensured by finishing them with the "old woman's tooth" or router plane. They should also be bored with the bradawl, as in Fig. 17; the nails used in fixing together will then be certain to go in the right direction.

reverse the stairs on the bench, and do the same with the other string.

The bottom edges of the risers must now be nailed to the back edges of the treads, and the front of the latter to the top of the former, as in Fig. 18, O and P. This will finish the stairs.

If preferred, the risers can be tongued into the treads, and the treads into the risers, as at R and S, Fig. 18. This is, however, not to be recommended, unless the treads are

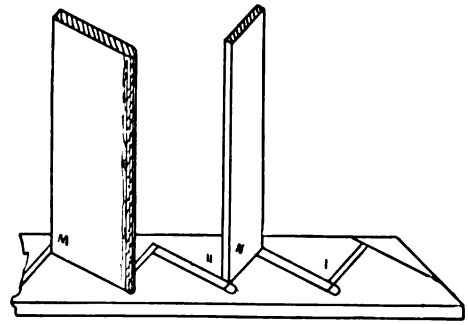

FIG. 15.—MARKING IN TREADS AND RISERS.

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$1\frac{1}{4}$ in. and the risers 1 in. thick, as shown. The tongueing and grooving will make no difference in the procedure, except that both the treads and risers will require to be a quarter of an inch wider.

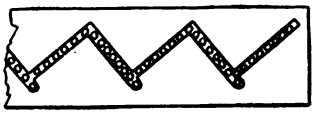

FIG. 16.
STRING BORED FOR HOUSING.

The treads, when grooved, must always be prepared before the nosing is worked; and the risers must be ploughed from the *top*

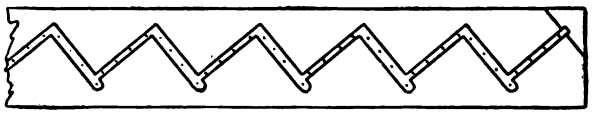

FIG. 17.—STRING WITH HOUSINGS CUT.

edge. In marking in, the grooves in each must be placed to the cut marks on the string boards.

In fixing the stairs, the wall strings must be made to intersect with the skirting, as in Fig. 19 at the bottom, and Fig. 20 at the top. This can always be done by cutting the string shorter or longer, as required. The same moulding as is worked on the skirting should be planted on the strings; and if the working of the segmental piece at the top (Fig. 20) is too difficult, this can be got over by bringing them to an obtuse angle.

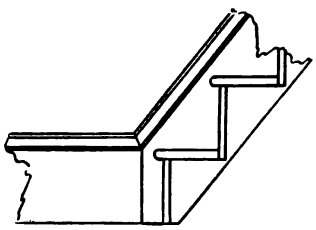

FIG. 19.—STRING INTERSECTING WITH SKIRTING AT BOTTOM.

The above method of making stairs will no doubt be new to many students; but it is an old one to the writer, who has made a great many in this way. For ordinary work it is preferable in every way to the usual method of wedging in the treads and risers. The latter will, however, be dealt with in the next article, when we shall show how to make a winding staircase to a definite plan.

Students may be recommended to make a model of the present stairs, including the landings, to a 3-in. scale—that is, quarter full size. Thus the full height would be 2 ft. $2\frac{1}{4}$ in., the full width, $8\frac{1}{8}$ in., the rise and going of each step, $1\frac{7}{8}$ in. and $1\frac{1}{2}$ in. respectively, the thickness being $\frac{1}{4}$ in. for the treads and $\frac{3}{16}$ in. for the risers. Each part should be done exactly as described above, and nothing omitted because it is small.

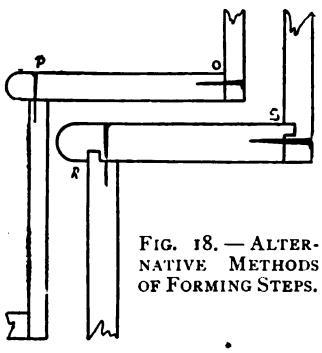

FIG. 18.—ALTERNATIVE METHODS OF FORMING STEPS.

The model, when finished, will form a valuable object-lesson, and the maker will have obtained an insight into the rudiments of the art of staircasing. Where a less systematic course is pursued, the student has to grope his way, instead of going ahead in confidence to the higher branches; and often the whole is thrown up in disgust.

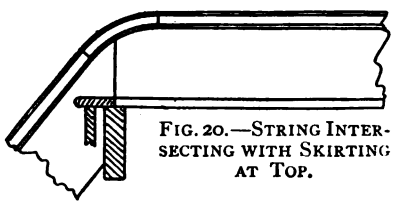

FIG. 20.—STRING INTERSECTING WITH SKIRTING AT TOP.

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DIRECT VISION SPECTROSCOPES.

By T. H. BLAKESLEY, M.A.

THE formation of a spectrum, whether by a prism, a train of prisms, or a grating, involves the angular separation, one from another, of the various rays of different colours comprised in ordinary white light. This angular separation is called *dispersion*, and may conveniently be measured from any selected ray. Thus, we read of spectroscopes of feeble power having a dispersion of 4°, and of those of stronger power with a dispersion of 12°, and so on. Each of these magnitudes refers to the angular distance between certain of the Fraunhofer lines in the spectrum produced by a particular instrument.

In many instruments, including some of the most powerful, dispersion cannot be produced without deflecting the whole of the rays from their original direction. Such an angular displacement is called *deviation*, and is quoted for some well-recognised ray. Viewed from this standpoint, dispersion between two rays is merely the difference between their deviations, and the essential difference between "direct vision" spectroscopes and others, is that in the former class the *deviation* of some central or selected ray has the value zero, whereas in the latter class the entire body of rays suffers angular displacement which is very large in comparison with the *dispersion* between the individual rays.

Thus in direct vision spectroscopes the telescope, camera, or other appliance employed to utilise the spectrum, may be pointed as if to receive the rays in their initial direction, and need only receive the small angular displacement from this position which is necessitated by the existence of *dispersion*. With instruments which are not of the "direct vision" class, the proper position for the telescope or camera must differ widely from that for the direct reception of the original beam, on account of the large angle of deviation.

It will thus be readily understood that direct vision spectroscopes, provided they involve no other drawback, must be better suited than others for many operations. For instance, they can be more readily attached to astronomical telescopes.

But unfortunately they are not, as a rule, so powerful as those possessing deviation. A direct vision spectroscope generally comprises prisms of two kinds of glass, arranged in a train with the refracting edge of each prism pointing in the direction opposite to that of the prism immediately preceding or following it. The prisms with refracting edges arranged on one side of the train are of one kind of glass, while the remaining prisms are made from another kind of glass. In this way the deviation of some given ray may be reduced to zero, while the dispersion remains finite. As the dispersion is the result of the differential action of the two sets of prisms, it will obviously be small unless many prisms are employed — an arrangement that would involve very great absorption of light.

There is another defect in direct vision spectroscopes of this kind. They are liable to produce anomalous dispersion, which means that the angular order of the rays in the resulting spectrum may not be the order of increasing or diminishing wave-length. That prisms of certain substances naturally produce this disorder, is well-known; but it is possible to produce it artificially by means of prisms of glass of different refractive indices.

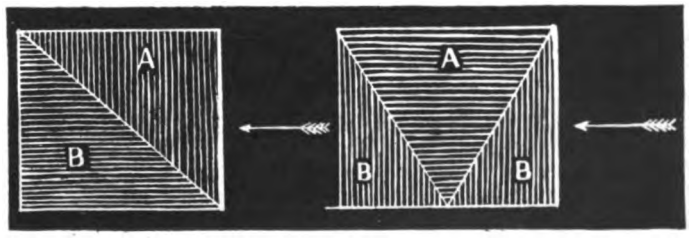

FIG. 1.

To explain this, let us consider either of the arrangements indicated in Fig. 1, where prisms marked A are of one, and those marked B are of another kind of glass. It is evident that rays, for which both kinds of glass have the same index, will pass through these systems without deviation, in a direction which may be called the axis of the instrument. Of the remaining rays, those for which the index of Glass A is greater

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than Glass B will be deflected toward one side of the axis, and those for which the index of B is the greater will be deflected toward the other side of the axis. Now it is quite possible to obtain glasses with equal indices for rays at two different points of the spectrum. These two different rays will be brought into coincidence with the axis, and the spectrum will be folded back upon itself, producing anomalous dispersion. Even if this extreme condition is not reached, anomalous dispersion might exist in some part of the spectrum, on account of irregularity in the run of the dispersion in different glasses. In the simple cases cited, if μ is the index of a certain ray for one kind of glass, and ν is the index of the same ray for the second kind of glass, the condition $\mu = \nu$ is all that is necessary for that ray to suffer no deviation, and this condition may hold for more than one ray. In other cases the condition may not be so easily seen, but there is always some condition which can be formulated by means of an equation involving the coefficients of refraction of the two glasses and the angles of the prisms, under which the ray will suffer no deviation; and this condition may be satisfied by more than one pair of values for μ and ν.

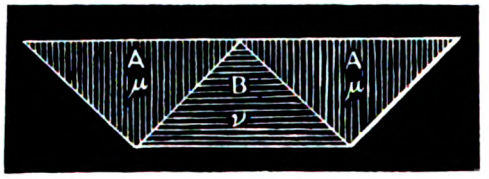

FIG. 2.

As an instance, suppose three isosceles prisms having refracting angles α, to be arranged as in the sketch, Fig. 2. The condition for no deviation in this case is:—

$$\text{Cos } \alpha = \frac{\nu^2 - 2\mu^2 + 1}{2(\mu^2 + \nu)}$$

Now it is quite possible that this equation may be satisfied for more than one ray of the spectrum, and even if this is not the case, the rays of the spectrum may be unduly crowded together and even reversed in order locally. It follows that considerable care must be exercised in selecting glasses for such instruments as utilise two refracting materials.

In the case last considered suppose that α is made equal to 90° the equation of condition then becomes

$$\nu^2 + 1 = 2\mu^2$$

and the case may be readily illustrated by putting a cube of glass into the corner of a rectangular tank of water, of which the sides are plates of glass. Here μ refers to the water, ν to the glass cube. If the D line is to suffer no deviation, and μ for the D line is taken as equal to 1·3336, the solution of the equation of condition is

$$\nu = 1{\cdot}59907$$

and we must select a glass which has this value for the index of the D line.

Had the F line been selected we should have for the indices:—

$$\mu = 1{\cdot}3378$$
$$\nu = 1{\cdot}60604$$

The difference of the indices of the glass for the two rays, or as it is called by Schott, the *partial dispersion* between D and F, would thus be 0·00697, a number not remote from what might be expected to occur in some sorts of glass whereof the index for D is 1·59907. There is little doubt that glass approximating to that here indicated would display anomalous or unduly irregular dispersion when employed with water as suggested above.

These are the scientific objections against employing two kinds of refracting materials in the way described, over and above those depending on the feeble dispersion and the high absorption of light. They might be overcome by employing, if it be possible, trains of prisms in which the deviation of one prism is not set against that of another.

A succession of prisms, of which the refracting edges all point across the general path of the rays in the same way, will produce a large dispersion and deviation in proportion to the number of prisms employed. If these are succeeded by a similar train of which the angles point across the rays in the opposite direction, the deviation and dispersion will both be annulled. But if, between these two trains, means can be found to reflect the whole beam so that rays which, before the reflection, were inclined to the right of the mean ray at a certain angle, are after reflection inclined to the left of it at the same angle (Fig. 3), and *vice versâ*; then the second train of prisms will increase the dispersion of the rays, while at the same

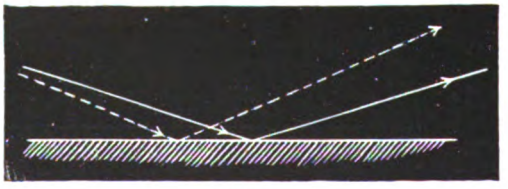
FIG. 3.

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time it diminishes the deviation of the beam generally. A simple reflecting plane mirror would have this effect, but would be subject to the defect that for the whole beam to be operated upon the mean ray would have to be incident at an angle considerably less than 90°. In other words, the mere reflection would create an extra deviation of the mean ray. To make up for this, the second train might be more or less numerous than the first. But it is unnecessary to resort to this plan, because an obtuse-angled isosceles prism may be employed as the reflector, the rays entering it by one of the equal sides being reflected internally by the base, and emerging at the second of the equal sides. If the mean ray is parallel to the base on entering the prism, it will also be parallel to it on leaving; and any other ray will make the same angle as before with the mean ray, but will now be on the opposite side of it. In the instrument about to be described this principle is employed, in conjunction with another which will now be explained.

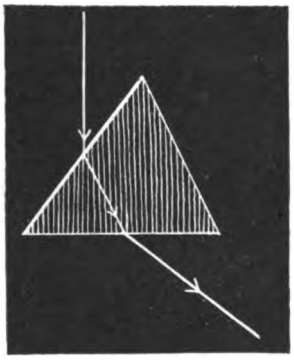

FIG. 4.

When a ray of light passes symmetrically through a glass prism, it receives a deviation D, which is connected with the angle of the prism, A, and the index of refraction μ of the glass for the ray, by the equation :—

$$\text{Sin } \frac{A + D}{2} = \mu \text{ Sin } \frac{A}{2}$$

If the angle A is chosen so that the deviation shall be equal to it (*i.e.*, if D=A,), then the equation takes the following simple form:—

$$\mu = 2 \text{ Cos } \frac{A}{2}$$

Thus the glass being chosen, and the particular ray, which is to suffer no ultimate deviation, being selected, we are in possession of μ, and the angle of the prism A is fixed by this condition.

In this case it follows that the ray of light before incidence must be at right angles to the side from which it is to emerge (Fig. 4), and on emergence the ray is at right angles to the side upon which it was first incident. The reversibility of the path of the light, and the fact that the deviation is equal to the angle of the prism, require this to be the case.

On emergence from this prism, the ray is made to encounter one of the equal sides of an obtuse-angled isosceles prism (Fig. 5) for the purpose already described. The base of this prism must be parallel to the ray on emergence from the first prism. Thus, on emergence from this second prism the selected ray will be still parallel to its course between the prisms. We are free to make the base angles of the second prism of what value we please, so long as the light is internally reflected from the base at an angle exceeding the critical angle of the glass; but if we make them equal to (90—A), then the two prisms can be made to come together and form one right-angled prism (Fig. 5). The cavity between the two prisms, having parallel sides, may now be done away with, and the prisms merged into one. As the necessary reflection now occurs inside the right-angled prism, the next prism can be placed across the emergent beam in such a way as to annul the deviation of the selected ray while increasing the dispersion generally. (Fig. 6).

FIG. 5.

The next two prisms, viz. : the 3rd and 4th, are images respectively of the 2nd and 1st, with regard to an imaginary plane at right angles to the direction of the light from the collimator. Thus, after passing the 4th prism the selected ray is in the same straight line as when it left the collimator, and can be received by the telescope, camera, or other apparatus.

It will be noticed that the angle of incidence or emergence of the selected ray, at each of the surfaces through which it passes, is equal to the angle A.

The collimator and the first two prisms are rigidly connected together, and the last two prisms and the telescope (if that be the instrument employed) are also rigidly connected. These two systems are moved relatively one to the other round an axis which is near the two adjacent angles of the second and third prisms. The course of the selected ray between the

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second and third prisms is parallel to *ef* (Fig. 6), but any other ray in that space will traverse a path making some angle with *ef*. In that case, if the system composed of the two last prisms and the telescope is turned until the ray considered passes symmetrically between the second and third prisms, that ray will finally leave the fourth prism with an angle of emergence equal to A, and be parallel with the axis of the telescope. This symmetrical passage implies minimum deviation through the train of prisms, and thus any ray which is brought into the centre of the field of the telescope has undergone minimum deviation through the train of prisms, and possesses the clearness of definition which that fact always implies.

The accompanying illustration (Fig. 7), reproduced from a photograph of part of the solar spectrum, was made with a lens of $14\frac{3}{4}$ inches focal length applied to a telescope magnifying ten times. When an arc lamp in which sodium is present is used as a source of light, then the spectrum of the light from the arc shows the second of the two D lines (*viz.* D_2) to be itself double. This seems an accomplishment for a spectroscope of only four prisms, especially with so small a magnifying power in the telescope.

The dispersion between the A and G lines is $18^\circ\ 20'$. During last year the instrument has been exhibited at Mercers' School, the Royal Institution, and before the Royal Society and the Physical Society of London. It is now provided with a telescope eyepiece which raises the magnifying power to 30. This step seemed warranted by the extreme brilliancy of the field with the lower powers at first provided. The line A and its region are admirably displayed, and the H lines are quite visible.

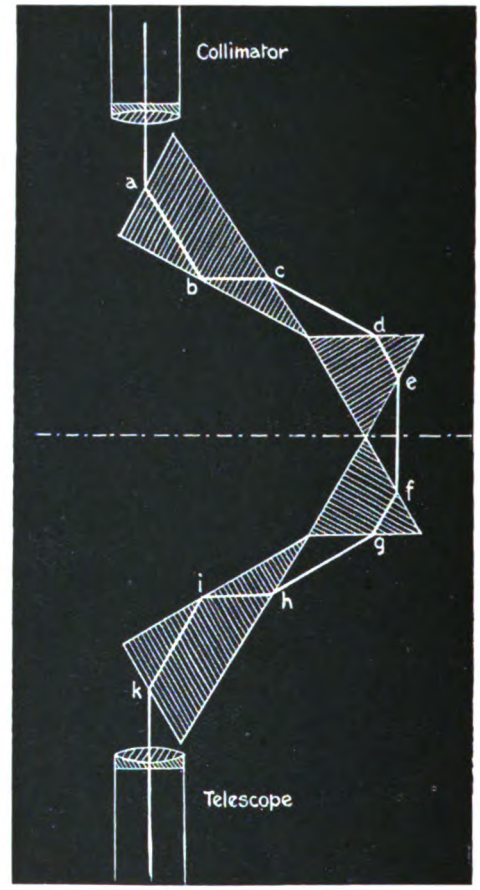

FIG. 6.

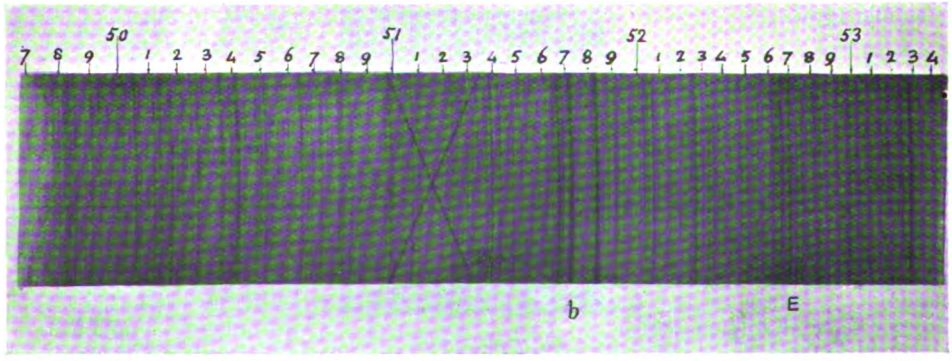

FIG. 7.—SOLAR SPECTRUM, SHOWING FRAUNHOFER LINES, BETWEEN 497 $\mu\mu$ AND 534 $\mu\mu$.

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THE CONTINUOUS-CURRENT DYNAMO.

PART IV.

By H. M. HOBART, M.I.E.E.

C.

THE INSULATION OF THE CONTINUOUS-CURRENT DYNAMO.

HAVING now obtained some understanding of the properties of the electric and magnetic conducting circuits, the subject of the intervening insulation comes up for consideration. In the average continuous-current dynamo, we have some hundreds of meters of copper conductor which must be suitably insulated from the magnetic circuit. The adjacent turns must also be insulated one from another. The final result is, that out of the total space provided to receive the insulated copper circuits, only a certain percentage is available for the copper. This percentage is less the higher the voltage of the machine. To increase the percentage for a given voltage, to the maximum consistent with sound insulation, is an important designing detail. In an armature slot or field spool, the ratio of the cross-section of the copper to the gross cross-section of the slot is designated as the "space factor" of the slot. A high "space factor" may be an indication that the space has been intelligently used, and that the insulation is sufficient for the requirements; or it may be an indication that insufficient space has been allowed for the insulation, which will consequently be weak. The importance of a study of the properties of insulating materials, and of methods of employing them to the best advantage, is not generally realised. If one were to judge from mere laboratory tests of materials, one would conclude that one millimeter thickness of almost any one of a great variety of materials would suffice to withstand an effective pressure of 5,000 volts. The curves in Fig. 29, which represent the results of laboratory tests on several different materials, point to this conclusion. Nevertheless, in practice it requires the greatest attention to detail, as well as care in the selection of materials, in order to build an armature employing only one millimeter thickness of insulation from the copper conductors to the iron core, which will stand—say, for one minute at 20° Cent.—the application of 5,000 effective volts from copper to iron. Few manufacturers are able to adopt so high as the half of this value as a standard test for completed apparatus built with this insulation allowance. Unless one is prepared to devote to this feature of armature construction, far more attention and expense than is customary, one millimeter thickness is too small an allowance. Mere thickness, however, is

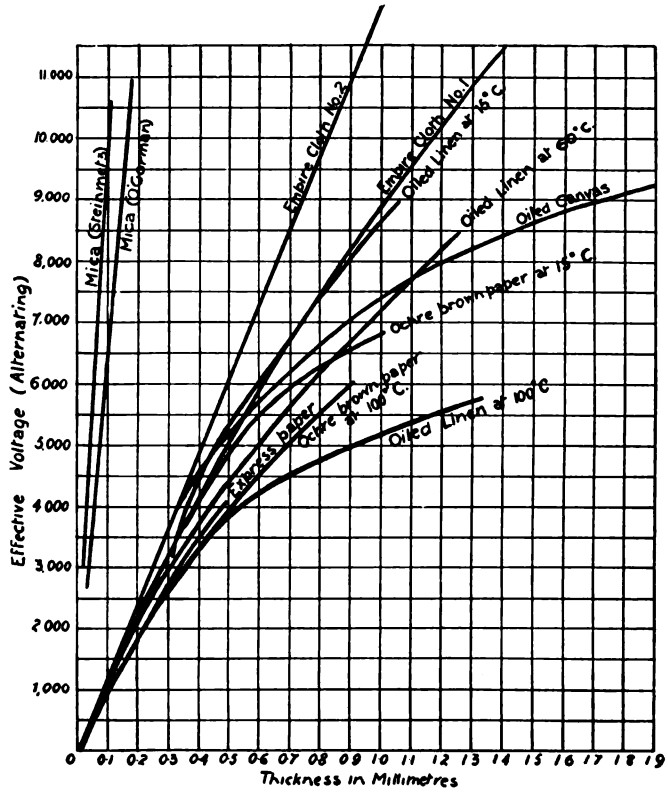

FIG. 29.—CURVES SHOWING DISRUPTIVE STRENGTH OF SAMPLES OF INSULATING MATERIALS.

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of little avail, since for most materials the disruptive voltage increases less rapidly than the thickness. For such materials double the thickness would not withstand double the voltage.

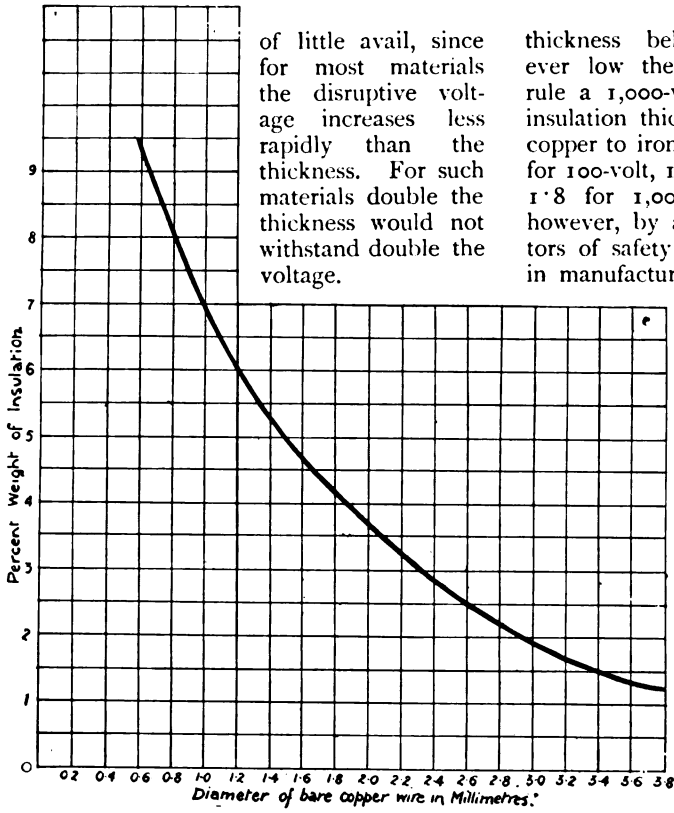

FIG. 30.—CURVE SHOWING THE PERCENTAGE BY WHICH THE AVERAGE COMMERCIAL "DOUBLE COTTON COVERING" INCREASES THE WEIGHT OF COPPER MAGNET WIRES.

In the writer's experience this is almost universally the case, and the only difference in different insulating materials in this respect relates to the extent to which the disruptive voltage deviates from proportionality with the thickness. Others, however, have come to the conclusion that by the choice of suitable materials the thickness need only be increased proportionately to the square root of the voltage.* Such a rule may be permissible for the narrow range of voltage (100 to 1,000 volts) employed in continuous-current dynamos. It is well, on the score of ensuring sufficient mechanical strength, never to reduce the thickness below 1·00 millimeter, however low the voltage. By Mr. Parshall's rule a 1,000-volt armature should have an insulation thickness of 1·8 millimeter from copper to iron. The use of 1·0 millimeter for 100-volt, 1·3 millimeter for 500-volt and 1·8 for 1,000-volt armatures, would not, however, by any means result in equal factors of safety in the three cases. With skill in manufacture the 100-volt armature could be subjected for one minute at 20° Cent. to a potential of some 2,000 effective volts, the 500-volt armature to 3,000 volts, and the 1,000-volt armature to 4,500 volts, the corresponding factors of safety thus being 20, 6, and 4·4. It is simply a matter of fact that present practice does not require so high a factor of safety at higher voltage, and so long as it is not required, it will, of course, rarely be provided by the manufacturers.†

In the matter of insulating materials, even the most progressive dynamo manufacturers are still groping in the dark. Nothing short of the most laborious, exhaustive, and painstaking investigations on a large number of materials, in the raw condition and also after treatment with various varnishes, and after being subjected to various processes,

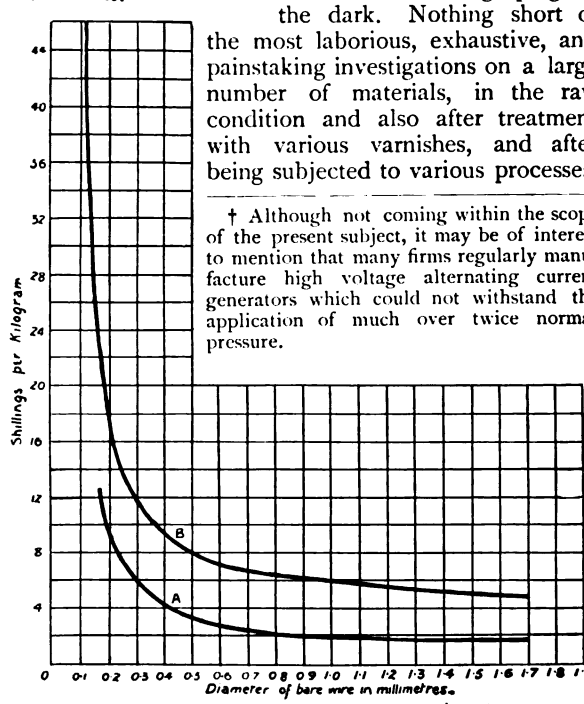

FIG. 31.—COST PER KILOGRAM OF DOUBLE COVERED MAGNET WIRES.
CURVE A—COVERING IS COTTON.
CURVE B— " " SILK.

* See H. F. Parshall, "Traction and Transmission," p. 1, vol. I.

† Although not coming within the scope of the present subject, it may be of interest to mention that many firms regularly manufacture high voltage alternating current generators which could not withstand the application of much over twice normal pressure.

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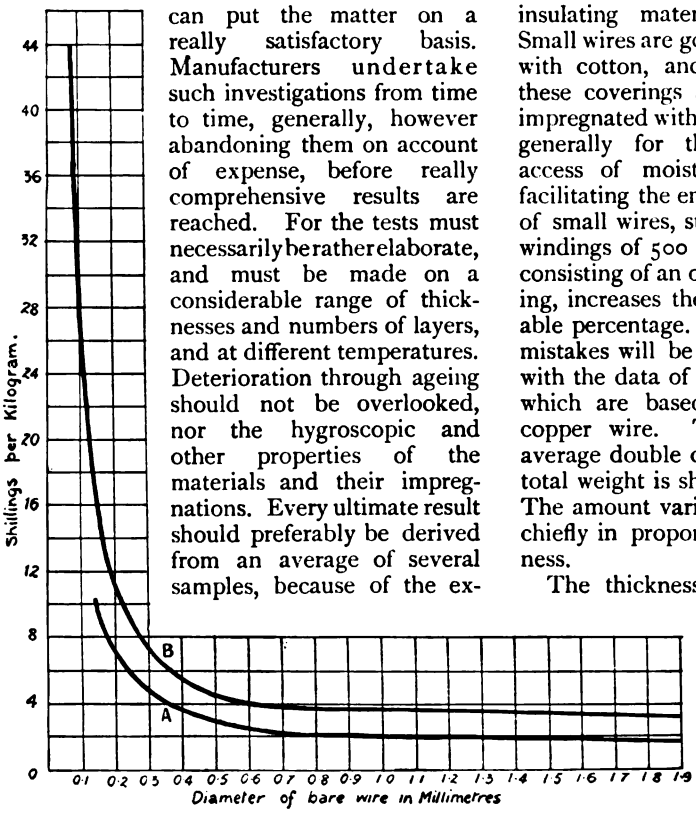

FIG. 32.—COST PER KILOGRAM OF SINGLE COVERED MAGNET WIRES.
CURVE A—COVERING IS COTTON.
CURVE B— ,, ,, SILK.

can put the matter on a really satisfactory basis. Manufacturers undertake such investigations from time to time, generally, however abandoning them on account of expense, before really comprehensive results are reached. For the tests must necessarily be rather elaborate, and must be made on a considerable range of thicknesses and numbers of layers, and at different temperatures. Deterioration through ageing should not be overlooked, nor the hygroscopic and other properties of the materials and their impregnations. Every ultimate result should preferably be derived from an average of several samples, because of the extreme variableness of even the most uniform of insulating materials. In conducting such tests it should be kept in mind that the continuous application of the voltage will often break down samples which will resist the same strain when applied for but a short interval. It is also of especial importance that the material shall have been thoroughly dried at a high temperature prior to testing, and preserved from access of moisture during tests. Some materials, however, which would be permanently affected by high temperatures, should before testing be preferably dried in a vacuum oven for a long time at a moderate temperature. It is very important that every detail regarding the conditions to which the material has been subjected, not only during, but before the test, should be recorded.*

The scope of this article will not permit of even enumerating the various excellent insulating materials now on the market. Small wires are generally spun over or braided with cotton, and sometimes with silk; and these coverings are sometimes subsequently impregnated with varnishes or other materials, generally for the purpose of preventing access of moisture, but recently also for facilitating the emission of heat. In the case of small wires, such as are used in the field windings of 500 volt dynamos, the insulation consisting of an ordinary double cotton covering, increases the total weight by a considerable percentage. If this is not kept in mind, mistakes will be made in reconciling results with the data of standard copper wire tables, which are based on the constants of *bare* copper wire. The amount by which an average double cotton covering increases the total weight is shown in the curve of Fig. 30. The amount varies to a considerable extent, chiefly in proportion to the stipulated thickness.

The thickness of cotton coverings given by a prominent concern manufacturing "magnet wires" is given in Table II.†

TABLE II.

SHOWING THICKNESS OF COTTON COVERINGS ON STANDARD ARMATURE AND MAGNET WIRES.

Double Lapping (Fine).

For all sizes up to 0·9 mm. dia. add 0·15 mm.
From 1·0 mm. dia. to 1·2 mm. dia. add 0·20 mm.
,, 1·4 mm. ,, 2·3 mm. ,, 0·25 mm.
For 2·6 mm. ,, and larger . add 0·30 mm.

Double Lapping (Ordinary).

For all sizes up to 1·2 mm. dia. add 0·25 mm.
From 1·4 mm. dia. to 2.3 mm. dia. add 0·30 mm.
For 2·6 mm. ,, and larger . add 0·35 mm.

A fine close *braiding* is generally 0·13 mm. to 0·20 mm. thicker than the ordinary double lapping.

Most manufacturers of electrical apparatus specify and obtain considerably thinner cotton coverings, though the thinnest coverings are only supplied at an increased price.

The use of silk-covered wire is sometimes preferable in small, high voltage, low speed dynamos, *i.e.*, in dynamos requiring many turns of fine wire; owing to the greater economy in space, and notwithstanding the higher cost. The thickness of a single layer of silk need not exceed 0·025 mm., as against at least double this amount for cotton.

* For detailed descriptions of methods of testing insulating materials, and of arranging results, see "Electric Generators," p. 43.

† Thickness of covering may be varied to a large extent to suit the user's requirements.

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The relative costs of single and double cotton and silk covered wires may be seen from the curves of Figs. 32 and 31.

Table III. gives approximate values for the relative thicknesses of silk and cotton covered magnet wires :—

TABLE III.

ROUGH AVERAGE VALUES FOR THE INSULATION THICKNESSES OF SILK AND COTTON COVERED MAGNET WIRES.

	Thickness of Insulation.
Single silk covering .	0·025 to 0·50 mm.
Single cotton covering	0·076 to 0·089 mm.
Double silk covering .	0·050 to 0·076 mm.
Double cotton covering	0·15 to 0·18 mm.

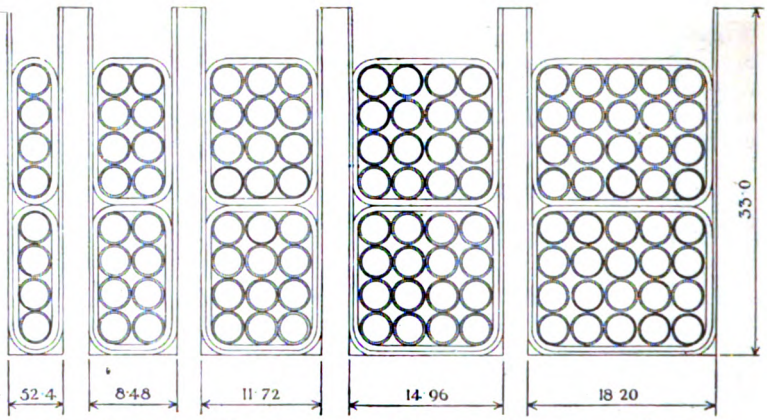

FIG. 33.—ARMATURE WINDINGS WITH DIFFERENT NUMBERS OF SEGMENTS PER SLOT.
(*The dimensions given are in millimeters.*)

Attention to these considerations is essential in obtaining a high space factor. While the thickness of the insulation on the individual conductors is of negligible influence in the case of large conductors, it can hardly be over-estimated in the case of fine wires. It is very essential to obtain a well-balanced understanding of this matter, as it is often given too much importance in some cases, and far too little in others.

Assume that a certain manufacturer finds by experience that he must, on his 500 volt continuous-current machines, employ a total thickness of 1·15 mm. from copper to iron, and that standard double cotton-covered wire should in general be employed. Although the thickness of double cotton covering decreases very slightly with decreasing diameter, it will suffice for the purpose of the argument to take it as constant at 0·15 millimeters. This leaves 1·00 millimeters insulation to be provided between the iron core and the double cotton-covered conductor. Suppose this to be made up of a slot lining, 0·4 millimeter thick, and a coil insulation 0·6 millimeter thick. Let us take the case of an armature wound with four turns per commutator segment, of double cotton-covered Number 11 S.W.G. The bare diameter of No. 11 S.W.G. is 2·94 millimeters. The double cotton-covered diameter is 3·20 millimeters. In Fig. 33 are shown arrangements with one, two, three, four, and five segments respectively, per armature slot, designed on the above assumptions as to required insulation. The space factors are as shown in Table IV. and in the lower curve of Fig. 35. These show that higher space factors may generally be obtained the fewer the number of slots—*i.e.*, the greater the number of conductors concentrated in one slot. This obviously leads to finding space for more copper on a given armature, hence to an increased output, so far as other considerations do not interfere.

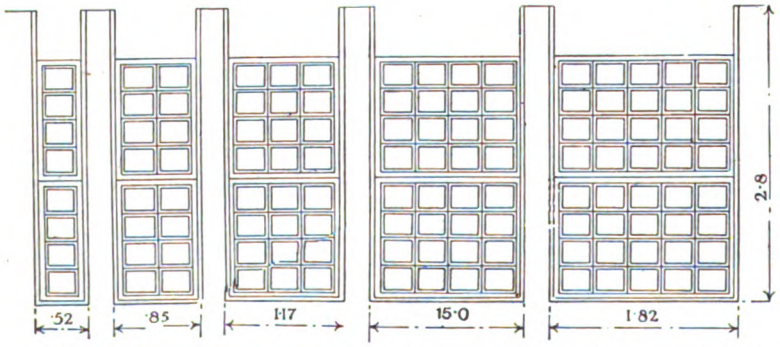

FIG. 34.—WINDINGS EQUIVALENT TO THOSE SHOWN IN FIG. 33, BUT WITH CONDUCTORS OF RECTANGULAR CROSS SECTION.
(*The dimensions given are in centimeters.*)

In Fig. 34 are shown equivalent windings with

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TABLE IV.

"SPACE FACTORS" FOR THE SLOTS AND WINDINGS OF FIGS. 33 AND 34.

Commutator Segments per Slot.	Turns per Segment.	Cross Section One Conductor in Square Cms.	Total Number of Conductors per Slot.	Total Copper Cross Section per Slot. (Copper Area).	Width of Slot. Cms. Fig. 33.	Depth of Slot. Cms. Fig. 33.	Area of Slot. Sq. cms. Fig. 33.	"Space Factor." $\left(\frac{\text{Copper Area.}}{\text{Slot Area.}}\right)$ Fig. 33.	For Fig. 34.—Width of Slot and Copper Area remain the same. Depth of Slot 2·8 cms.	
									Area of Slot. Sq. cms. Fig. 34.	Space Factor. Fig. 34.
1	4	·068	8	0·544	0·524	3·3	1·73	·314	1·465	·371
2	4	·068	16	1·09	0·848	3·3	2·80	·39	2·37	·460
3	4	·068	24	1·63	1·172	3·3	3·87	·421	3·28	·498
4	4	·068	32	2·18	1·496	3·3	4·93	·443	4·18	·522
5	4	·068	40	2·72	1·820	3·3	6·00	·454	5·09	·535

conductors of rectangular cross section. The saving has been taken advantage of to decrease the depth of slot. The space factors are 18 per cent. higher than before as shown in Table IV., and by the upper curve of Fig. 35. Such a winding would be considerably more expensive in labour, and there is often but little gained by making the slots shallower; but the saving could be employed to increase the output, the slot depth remaining the same, and the example emphasises the important conclusion that the use of rectangular conductors may be accompanied by considerably higher space factors, and hence in general, is a legitimate means for obtaining a high output from a given outlay on material. The amount of the gain is variable, depending upon the required cross section, and upon the ratio of the two dimensions of the rectangular conductor: this ratio being often determined by considerations of what it is practicable to wind. It may in general be said that conductors of square cross section, while leading to the highest space factors, are to be avoided on account of difficulties in winding. The ratio of the two dimensions should preferably be at least 1 : 1·5, and this materially detracts from the advantages to be derived from the use of rectangular conductors, so far, at least, as relates to increased space factor. Even with conductors of this proportion, a very considerable gain is, however, secured.

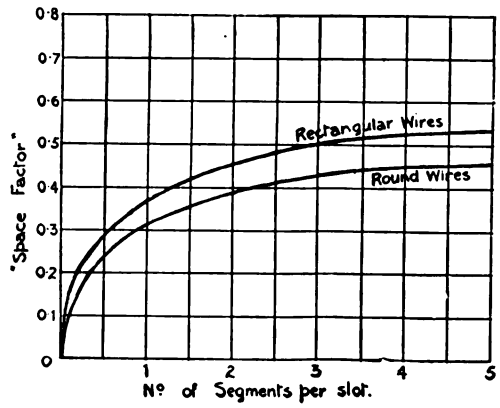

FIG. 35.—GRAPHIC REPRESENTATION OF "SPACE FACTORS."

In Fig. 36 are shown, for purposes of illustration, two slots containing, first, two No. 4 S.W.G. (bare diameter 5·9 mm.) conductors per slot, and then two conductors of equivalent rectangular cross section per slot. It should be noted that the left-hand slots of Figs. 33 and 34, *i.e.*, those with but one commutator segment per slot, have the same total cross section of copper per slot as the slots of Fig. 36. Using slots with the same equivalent copper cross section, but subdivided into 5, 4, 3, and 2 turns per coil, we obtain the group of slots shown in Figs. 37 and 38, from which Table V. and Fig. 39, showing the resulting "space factor," have been derived.

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TABLE V.

"Space Factors" for the Slots and Windings of Figs. 37 and 38.

Commutator Segments per Slot.	Turns per Segment.	Cross Section of one Conductor. Sq. Cms.	Total number of Conductors per Slot.	Total Copper Cross Section per Slot (A).	Width of Slot for Fig. 37. Cms.	Depth of Slot for Fig. 37. Cms.	Width of Slot × Depth of Slot for Fig. 37. Sq. Cms. (B).	"Space Factor" A + B for Fig. 37.	Width of Slot for Fig. 38. Cms.	Depth of Slot for Fig. 38. Cms.	"Space Factor" (A + B for Fig. 38.
1	1	·274	2	·544	·82	2·02	1·62	·317	·82	1·77	·385
1	2	·137	4	·544	·647	2·56	1·65	·302	·647	2·21	·383
1	3	·0910	6	·544	·570	3·00	1·71	·291	·570	2·57	·374
1	4	·0685	8	·544	525	3·38	1·77	·281	·525	2·875	·364
1	5	·0548	10	·544	·494	3·72	1·84	·271	·494	3·155	·352

From the examples in Figs. 33 to 39, we see how vitally the arrangement of conductors and their dimensions, affect the value of the space factor obtained; and when we recollect that these all relate to a small range of variations, no surprise will be occasioned by the statement that, in practice, armature space factors range from much less than 0·1

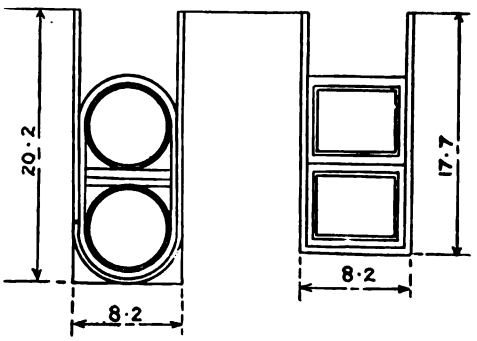

Fig. 36.—To Compare Armature Windings with Conductors of Circular and Rectangular Sections.

up to over 0·7, according to the rated capacity, voltage, and speed.

It is difficult to define the lines of design leading to the highest space factor. This is a matter for careful examination and arrangement in each case. Nevertheless, certain general statements may serve as useful guides:—

The space factor will generally be higher the lower the voltage, the higher the output, the higher the speed, the less the number of slots into which the winding is subdivided; and the greater the skill and knowledge employed in the processes of winding and insulating, and in the selection and testing of insulating materials.

The shaded area, included between the two curves of Fig. 40, is the locus of the space factors of the armature slots of motors of from 1 to 100 h.p. capacity, designed for customary speeds and in the light of present knowledge.

For 600-volt motors the values approach

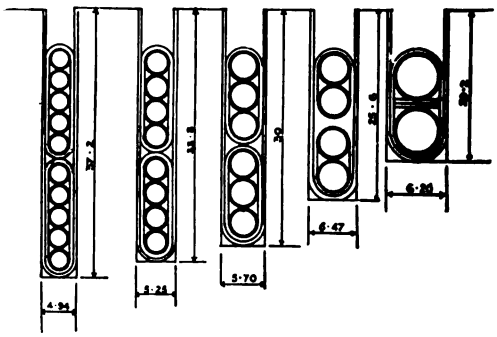

Fig. 37.—Windings with the same Copper Cross Section as in Fig. 36.

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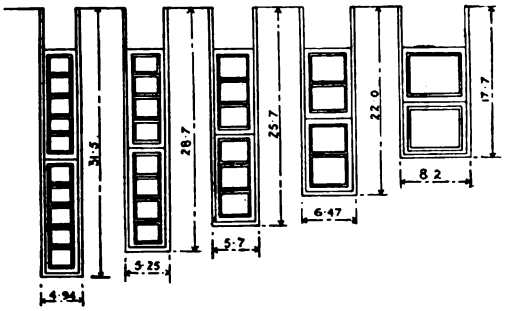

FIG. 38.—TO ILLUSTRATE WINDINGS WITH EQUIVALENT COPPER CROSS SECTIONS.

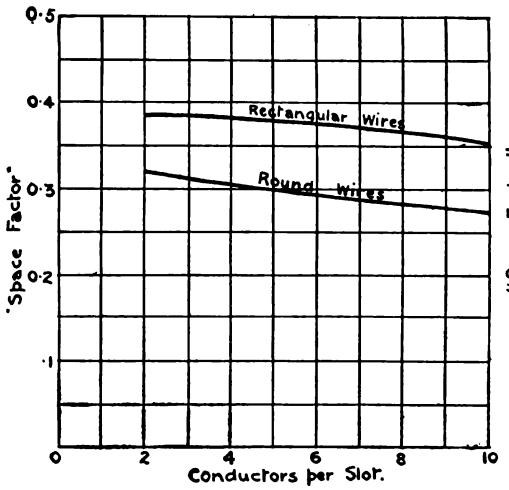

FIG. 39.—GRAPHIC REPRESENTATION OF "SPACE FACTORS."

the upper limit of the shaded area, and for 100-volt motors, the lower limit. Such "space factors" are, with careful attention to details of insulating, consistent with the application of the following insulation tests to the completed armatures :—

Rated Voltage.	Guaranteed Insulation Test from Copper to Iron at 60° Cent. for one minute.
100	2,000 R.M.S. volts.
600	3,600 R.M.S. volts.

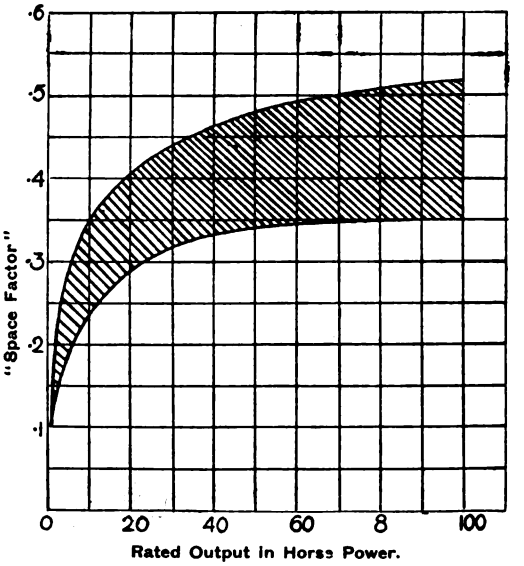

FIG. 40.—"SPACE FACTORS" FOR ARMATURE SLOTS OF SMALL CONTINUOUS-CURRENT MOTORS.

TABLE VI.

"SPACE FACTORS" FOR THE SLOTS OF FIGS. 42 AND 43.

Number of Conductors per Slot.	Diameter of Conductors. m/m.	Cross Section of one Conductor. Sq. Cms.	Total area of Conductors per Slot.	"Space Factor" Ordinary Insulation (Fig. 42).	Diameter of Conductors. m/m.	Cross Section of one Conductor. Sq. Cms.	Total area of Conductors per Slot.	"Space Factor" Half Ordinary Insulation (Fig. 43).
32	1·47	·0147	·544	·273	1·62	·0206	·66	·332
50	1·114	·010	·50	·251	1·264	·0125	·625	·314
72	·88	·0062	·448	·225	1·03	·0083	·60	·30
98	·71	·0040	·39	·196	·86	·0051	·57	·276

Corresponding to such motors, the shaded portions of the six rectangles of Fig. 41 * show the proportions of the total slot area occupied by copper and insulation respectively. The proportions do not reflect creditably upon the state of present knowledge of the subject. If, for instance, as is evident from the lower left-hand rectangle, we could reduce the amount of space required for insulation in the proportion of four to three, we could either enormously increase the output of the motor in question, or correspondingly greatly improve its efficiency. This is an example of the numerous cases where the use of silk-covered wire is the

* Figs. 40 and 41 are taken from "Traction and Transmission," vol. v., pp. 104–5.

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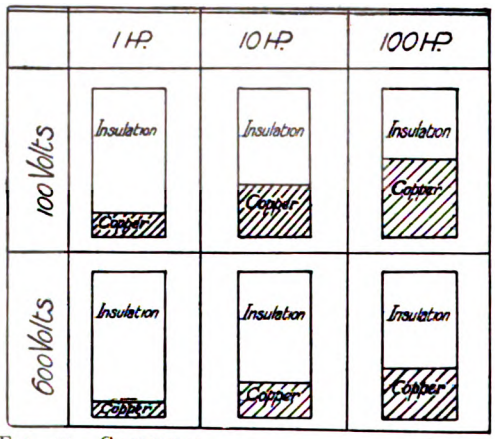

FIG. 41.—GRAPHICAL REPRESENTATION OF RELATION BETWEEN TOTAL SLOT AREA AND TOTAL COPPER CROSS SECTION IN SMALL CONTINUOUS CURRENT MOTORS.

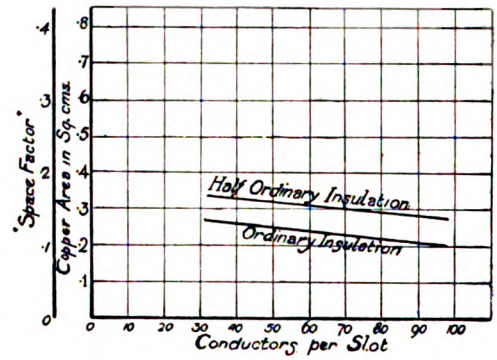

FIG. 44.—SPACE FACTOR AND COPPER AREA: SLOT AREA CONSTANT THROUGHOUT.

only rational and economical practice, benefitting both manufacturer and customer.

Two main considerations demand attention. First, *the space devoted to the slot lining and the "coil" insulation.* This space is decreased by concentrating the conductors in few slots. Secondly, *the space occupied by the insulating covering on each conductor.* This latter, for a given voltage, leads to rapidly increasing percentages of lost space, the smaller the motor.

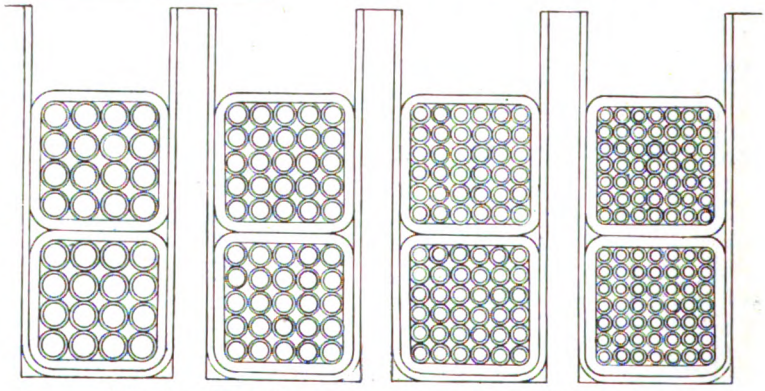

FIG. 42.—WINDINGS WITH MANY CONDUCTORS PER SLOT.
(Size of slot 9·07 mm. × 21·94 mm.)

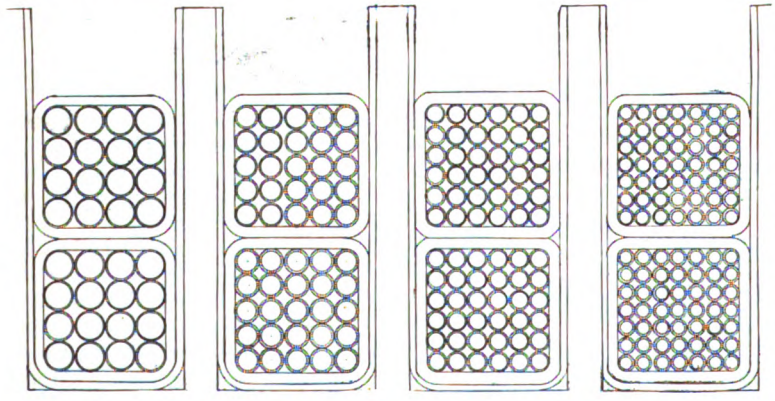

FIG. 43.—WINDINGS SIMILAR TO THOSE REPRESENTED IN FIG. 42, BUT WITH THE INSULATION HALVED.
(Size of slots as in Fig. 42.)

Fig. 37 represents the arrangements for a given total cross section of copper per slot, when there are respectively 5, 4, 3, 2, and 1 turns per segment. Dealing with much finer wire, we may illustrate the case by the four slots shown in Fig. 42. Here we have respectively 32, 50, 72, and 98 conductors per slot, arranged 4 × 8, 5 × 10, 6 × 12, and 7 × 14. The dimensions of the slot, the slot lining insulation, the coil

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insulation, and the insulation thickness on each conductor, conform to our original assumption, and the total copper cross-section per slot falls off, as shown in the lower curve of Fig. 44.

In the next figure (Fig. 43) the thickness of insulation on each conductor is halved, the other insulations remaining unchanged, and the space gained is employed by increasing the cross section of the copper conductors. The respective space factors then become as shown in the upper curve of Fig. 44 and in Table VI. The improvement is not so obvious from a comparison of Figs. 42 and 43, but is very marked in the curves of Fig. 44 and in Table VI., showing an average gain of 33 per cent. in the amount of copper and hence in the space factor.

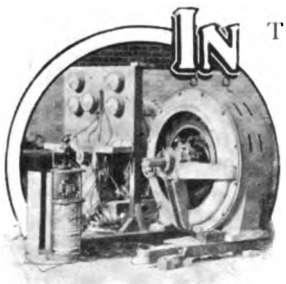
Now silk coverings less than 75 per cent. of the thickness of cotton coverings may, in practice, be obtained, and a double covering affords ample security against breakdowns, since the voltage between adjacent wires is very low.

Suitably impregnated single silk coverings are practicable in some cases, and permit of still further improvement. A compromise arrangement sometimes employed consists in the use of wires covered with one layer of silk and one layer of cotton.

(To be continued.)

ON THE EDUCATION OF ELECTRICAL ENGINEERS IN LONDON.

By Dr. J. A. FLEMMING, F.R.S., Professor of Electrical Engineering in University College, London, Vice-President of the Institution of Electrical Engineers.



IN THE next place, reference must be made to the engineering schools of the principal Polytechnic Institutes. In many of these, notably at The Northampton Institute, Clerkenwell; The East London Technical College; The Woolwich, South Western, and Battersea Polytechnics, the Goldsmiths' Institute, and the West Ham Technical Institute, very finely equipped engineering and electrical engineering departments exist, placed under the control of competent teachers. In many cases, such as that of the Northampton Institute, such importance is attached to the engineering departments that the Principal of the college, Dr. R. Mullineux Walmsley, himself takes charge of it, in addition to his duties as Principal of the college. In all of the eleven Polytechnics and Technical Institutes mentioned at the beginning of this article, there are well-equipped electrical and Mechanical Engineering Laboratories. The evening classes in these subjects are very popular, and these alone attract an attendance of 4,242 students in all.

Northampton Institute

Broadly speaking, the courses of instruction in electrical engineering in all these institutes follow very much on the same lines. The teachers are invariably selected for their practical knowledge of some branch of the subject and ability to teach it. The syllabus generally comprises elementary and advanced courses of lectures, intended to prepare the way for practical work by giving the students systematic instruction in the scientific principles which underlie the application of electrical and magnetic facts in engineering.

In most cases these courses are followed out with references to the requirements of the examinations of the City and Guilds of London Technical Institute, and in the

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more completely equipped institutions, with reference also to the syllabus of the University of London examinations for degrees in engineering. College examinations and prizes and scholarships serve as a stimulus to students to take advantage of their opportunities.

Equipment of Polytechnics

As regards instrumental equipment and accommodation for students, the leading London Technical Institutes and Polytechnics are in advance of the older colleges, such as King's and University College; at the same time, the students' fees for even the day instruction are much less, whilst the fees for the evening classes are in many cases merely nominal.

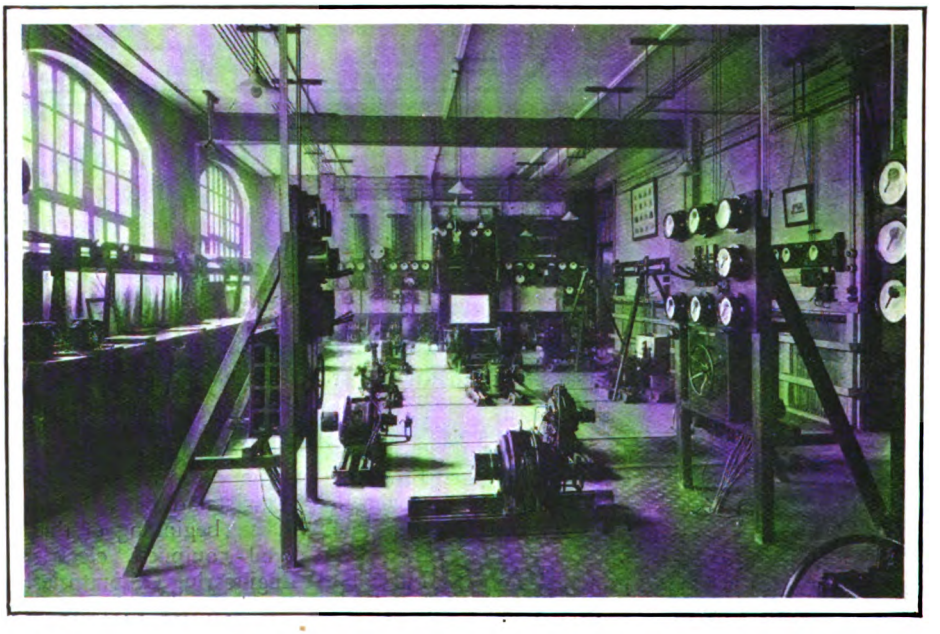

Photo by DYNAMO ROOM, NORTHAMPTON INSTITUTE. *George Newnes, Ltd.*

In about seven of the polytechnics engineering classes are conducted in the daytime, but their chief work is imparting scientific and technical education to men engaged during the day in practical work. Hence, from 7 P.M. to 10 P.M. their lecture rooms and laboratories are crowded with students. These evening students are mostly drawn from the ranks of those employed during the day in some of the many engineering and electrical trades, eager to take advantage of the polytechnic training to obtain instruction in the theory of the work they are doing and fit themselves for advancement in practical business. Accordingly, in many cases the polytechnics bestow particular attention upon the technical teaching which has reference to local trades. For example, in Clerkenwell there are numerous electro-platers, electrotypists and electro-chemists. Accordingly, in the Northampton Institute there is a well-arranged electro-chemical laboratory, and a series of lectures and laboratory courses in electro-chemistry.

Whilst, primarily, the aim of the polytechnics is to give instruction in the scientific principles underlying the various technical applications, a certain amount of instruction is also given in what are called the trade classes. In these the handicraft skill is developed as well as an intelligent knowledge of the reasons for certain processes and methods.

Trade Classes

Instruction in practical electric wiring and electrical instrument-making is also a feature in the work of the Northampton Institute, the East London Technical College, the South-Western Polytechnic, and the Battersea Polytechnic.

The extent and scope of the theoretical and practical work conducted in these institutions speaks volumes for the care with which they have been organised.

In fact, a study of the syllabus of the

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Northampton Institute, merely in the department of electrical engineering, is a revelation as to the range and value of the teaching being conducted by Dr. Mullineux Walmsley and his talented coadjutors.

When it is remembered that the advantages of this splendid teaching, and these wonderfully well-equipped laboratories are at the disposal of students for merely nominal fees, we cannot but feel that the work is one which must be powerfully assisting, although perhaps in a quiet and unostentatious manner, the industrial work of London.

Space will not permit of a detailed description of the syllabuses or the appliances of these various polytechnics in which electrical engineering teaching is being conducted, but it may be useful to summarise the attendance at these various colleges, simply to show the total quantity of teaching being done. By the kindness of the various principals of the polytechnics and professors of the colleges, figures have been obtained for the total number of engineering students, day and evening, now being trained in London, and, so far as possible, these have been separated into the mechanical and electrical engineering students. As a certain amount of overlapping exists, the figures cannot be precisely accurate, but they are so approximately. As there is no desire to exhibit the colleges or polytechnics in rivalry to each other in numbers, only the gross totals are given, but these are sufficient for our purpose.

Numbers of Students

Approximate number of Engineering Students, Day and Evening, in Mechanical and Electrical Engineering, now being trained in London in the Colleges and Polytechnics.

Institutions.	Day. Mech. Eng.	Day. Elec. Eng.	Evening. Mech. Eng.	Evening. Elec. Eng.
Central Institution Finsbury College University College King's College	818		672	
Goldsmiths' Institute Paddington ,, Northampton ,, West Ham ,, Battersea Polytechnic Chelsea ,, Regent Street ,, Borough ,, Northern ,, Woolwich ,, East Lond. Tech. Coll. Faraday House	454		4,242	
Total	1,272		4,914	

The total number of students in the four principal colleges cannot be precisely divided into electrical and mechanical, as the same student often attends both departments. In the case of the polytechnics also there is some overlapping, but it is believed that the above figures are fairly accurate; at least, in the grand totals.

Taking day and evening students in both mechanical and electrical engineering, there are, therefore, not far from 1,300 day students and 5,000 evening students working in London. In the Berlin Technical High School, at Charlottenburg, there were, in 1902–1903, 1,820 day students taking regular courses of study in Mechanical and Electrical Engineering (see "Technics," Jauuary Number, p. 15). Hence, when people talk about the Berlin Charlottenburg and its 4,500 students in *all branches* of technology, as if that were something extraordinary, it should be noted that in the colleges and polytechnics together in London we have in engineering students alone, day and evening, at least an equal number; whilst in regard to day students taking complete courses, we have altogether, in London, about two-thirds of the number in Berlin. On the other hand, whereas they are collected *en masse* in Berlin, the numbers are distributed over about seventeen institutions in London.

Comparison with Charlottenburg

An army, however, is not to be estimated by mere numbers. Organisation is everything. What we lack in London in the engineering teaching is coherence, specialisation, and interconnection.

A letter in the *Times*, from Lord Rosebery, started into existence, or, rather, into publicity, a scheme which is generally mentioned by the newspapers as that for a "British Charlottenburg." This title, like most pat newspaper phrases, is somewhat objectionable. It suggests the idea that we are about to slavishly imitate a German institution, and that our efforts to make up national deficiencies in higher technical education are to take the form of copying the Berlin Technical High School. As a matter of fact, the problems presented by London's educational needs are very special and complex, and will call for the highest constructive statesmanship to solve them in a satisfactory manner. London is a very large city, and mere distance is a factor which has to be taken into account. Moreover, we have not a clean sheet of paper to start upon, but have to take account of the existence and interests of the present institutions.

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Defects in our Present System

Nevertheless, we can state in a few brief words what are the chief defects in the present provision for engineering education in London, and some of the difficulties which have to be surmounted.

First, as regards the 1,200 or more day Engineering students, we have these scattered about in four colleges and about seven polytechnics, and there is, therefore, a vast amount of needless overlapping and multiplication of teaching. The consequences are that the principal professors are occupied in doing much elementary teaching, the mere A B C of their subjects, whereas, many being specialists of the first rank, they should be engaged in teaching advanced special branches of the subject. There is also waste of power in the junior teaching staff.

In the next place, the appliances and plants have been chosen in each case rather in view of the funds and space available than with respect to ideal requirements.

Financial Difficulties

Thirdly, and most important of all, owing to the *res angusta domi*, the debt-crippled financial state of some of these higher colleges, the professors have had to spend much of their energies and some of the best years of their lives in heart-breaking struggles merely to collect the means to obtain apparatus and rooms in which to work, or the wherewithal to pay their often inadequately-paid assistants. The public purse-strings can only be relaxed by an appeal to some emotion, and the higher scientific teaching appeals only to the head, and not to the heart.

On the other hand, there are great difficulties in the way of concentrating all the engineering day teaching in a single institution, say, at South Kensington. The engineering departments in the existing colleges form a valuable asset, and, even if we suppose their professors, assistants, students, and apparatus carried off and plumped down in one common building, it would inflict damage to the colleges. Thus the total students' fees paid in at University College, London, amount to about £17,000 a year, and of this £4,000 comes from the engineering students alone; and of this latter sum about £2,000 is paid for teaching, such as physics, mathematics, chemistry, etc., not given by the engineering professors. Hence, to cut away the engineering department without some form of compensation would be to inflict an injury.

Again, the Central Institution and Finsbury

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College form part of a complete educational edifice, erected by the City and Guilds of London, and difficulties would no doubt present themselves if this were disturbed. Therefore, it is not an easy matter to work out a scheme for the amalgamation of the teaching of the engineering day students in London. Nevertheless, it is essential it should be done.

The ideal requirement of the University of London is undoubtedly a College of Engineering in which all the day teaching and advanced research on this subject could be conducted. In this, the present professorial and teaching staff scattered about London could be concentrated, specialised, and provided with adequate means for teaching and research. Entrance could be restricted by examination, students' fees unified and reduced, and combined effort achieve what is now impossible. Meanwhile the polytechnics could continue to do their admirable evening work, and send up their picked students with scholarships to the above Higher College.

Concentration Needed

If this is not practicable, then the existing colleges should be assisted and some sort of specialisation introduced, but there are difficulties from want of space for extension in some cases.

The equalisation of fees can only be brought about by proper endowment of the unendowed institutions. Merely to overtop the existing colleges by some new institution which might rival and ruin them would be manifestly an injustice. What we require is not so much the means to make more engineering students, as the organisation to make better ones.

Equalisation of Fees

We want to bar the entrance to the profession to the incompetent and ill-prepared, even if well-to-do, lad; but to open fresh opportunities to the young man with proper preparation, brains, energy, perseverance, and, above all, inventive and constructive power, no matter in what rank of society.

We need for the teachers better opportunities for research: for dealing, by combined effort, with problems in engineering, which isolated individual spasmodic effort cannot touch. In short, we require a living organisation, and not a conglomeration of isolated institutions.

This desired end will not, however, be accomplished merely by the erection of a new big building, even if stocked with apparatus and plant from basement to roof. We must have first, the well thought-out scheme; secondly, the capable organisers; thirdly, financial aid; and then permit the scheme to develop in the hands of experienced teachers.

At the present moment the absence of all endowment in some of the higher colleges, and the competition for students, compels them to take in as an engineering student anyone, no matter how ill-prepared or unfit he may be. Hence much of the teaching has to be adapted to the capacity of those who start without preliminary scientific training, and with a mere schoolboy knowledge, or rather ignorance, of mathematics, physics, and chemistry.

The amalgamation of the teaching of the engineering day students, or at least, of the advanced day students, in London in one common building would enable an organisation to be effected which would vastly increase its efficiency.

By entrance and session examinations, the imperfectly prepared or idle students could be weeded out; and by the insistence on a complete course of instruction for all, the scrappy kind of education so much in evidence at present could be prevented. A young engineer who passed through such a training would be placed in a vastly better position to hold his own with his competitors in America and Germany, and to take his share in solving the problems which every day present themselves to the practical engineer.

When we compare the accommodation and appliances of some of our higher colleges in London, such as University College, King's College, and Finsbury with those which exist or are growing up in the large provincial cities, Birmingham, Liverpool, Manchester, Leeds, Sheffield, or even in the best of London polytechnics, to say nothing of the American or Continental colleges, we can only arrive at the opinion that the apathy of London citizens in the matter of the higher technical education is amazing.

Is it due to a real indifference in this great city to the importance of the issues at stake, or to any want of vigour on the part of the colleges in making known the needs of their engineering departments? No doubt the difficulties of organising more completely the engineering teaching in London are great, but great also are the benefits to be obtained from a satisfactory solution of the problem.

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THEORY OF STRUCTURAL DESIGN.

PART IV.

By E. FIANDER ETCHELLS, A.M.I. Mech.E.

THE concluding paragraphs of the article in last month's issue dealt with the bending moment in a built-up cambered girder, resting on practical bearings, as compared with the bending moment on an imaginary beam supported on knife edges at a distance apart equal to the overall length of the beam. It was shown that in practical work we should employ the effective span in our $\frac{w\,l^2}{8}$ formula, where $w\,l$ represents the portion of the load lying between the centres of supports.

Let us now take up the case of a rolled steel joist, resting on a brick wall or other similar support, but not built into the brickwork (see Fig. 25).

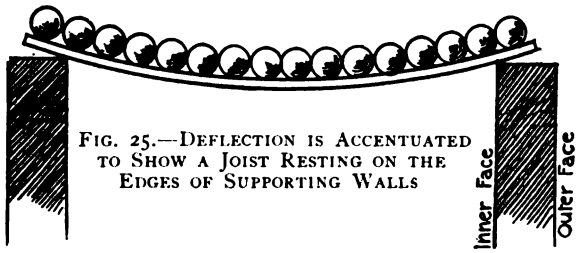

FIG. 25.—DEFLECTION IS ACCENTUATED TO SHOW A JOIST RESTING ON THE EDGES OF SUPPORTING WALLS

In the case of rolled steel joists in floor or bridge-work, it is not usual to have any initial camber, and the joists are often cold-straightened before leaving the engineer's yard.

The calculation of the distribution of pressure over the bearing surfaces is really a very intricate and tedious task, and, moreover, it would contain too many assumptions to be absolutely trustworthy. The distribution of the bearing pressure depends upon such factors as the following: the length of the girder, the depth, the distribution of the girder load, the shape of the cross-section, the elasticity of the steel, the presence or absence of initial straightness in the beam, the elasticity of the supporting brickwork, etc. The distribution of bearing pressure also depends upon whether the supporting walls are vertical and of exactly the same height, and whether the bearing surfaces are absolutely true. It also depends upon the nature of the packing, etc. The distribution of pressure is affected by changes of temperature, even on the face of the supporting wall; and is dependent upon a number of other factors quite outside the control of the designer.

Having stated the difficulties of an exact solution, let me try and show how a *safe* answer may be obtained with little previous knowledge and a simple experiment.

Experiment No. 1.—Lay the long thin blade of a T-square across the gap between two tables of equal height. Load this improvised beam with one or two paper weights. The end of the T-square will be seen to tilt up, and the edges of the table will give the position of the two upward reactions. This represents the state of affairs with a long and shallow beam on rigid supports. (See Fig. 25.)

Experiment No. 2.—Lay a block of iron, or a rectangular paper weight, across two very soft pieces of india-rubber, as indicated in Fig. 26. All vertical sides of the rubber will appear to be bulged equally, and no difference of pressure will be indicated in passing from A to B. The centre of pressure may be safely assumed to lie midway between these points. This approximately represents the state of affairs in a short, exceedingly stiff, straight joist on comparatively compressible supports. It is an extreme case, and is merely given as an accentuated illustration of the outside limit.

Let us define the effective span as being the span between the centres of pressure of the reactions. In experiment No. 1, the

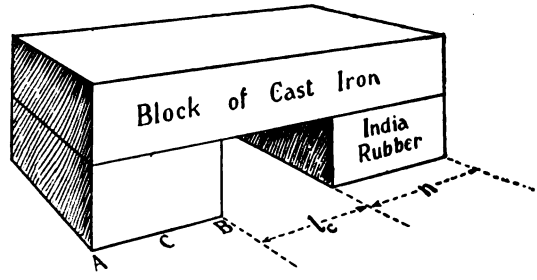

FIG. 26.

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effective span was equal to the clear span. In experiment No. 2, the effective span = clear span + length of one bearing = $l_c + 2\left(\frac{n}{2}\right)$ (*See* Fig. 26).

In practice, and with a straight joist, the effective span will be somewhere between the values given by the experiments, and will approach one value or the other, according to the stiffness of the girder, etc. In other words, the position on the centre of pressure under straight joists will lie somewhere between the centre line of the supporting wall and the inner face of the wall.

Let us take the mean between these extremes, and assume that the centre of pressure will lie at a distance of $\frac{n}{4}$ inches from the inner face of the wall.

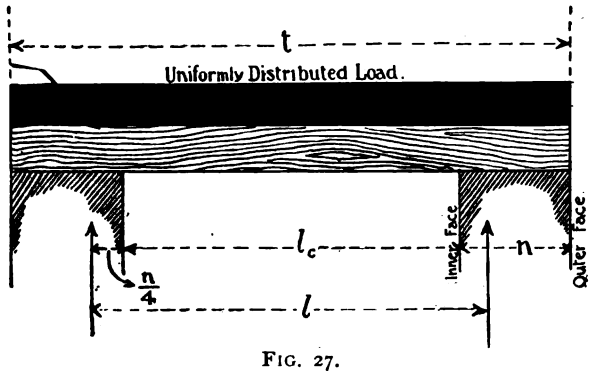

FIG. 27.

Acting on this assumption, let us take out the maximum bending moments for the case illustrated in Fig. 27.

Let t = total length of girder in inches.
„ l_c = clear span in inches.
„ l = effective span in inches.
„ n = length of bearing in inches.
„ w = combined weight of joist and load on the joist in tons per inch run.
„ W_t = total weight of joist + load on the joist = $w\,t$.
„ $W = w.l$ = total weight which lies between the centres of upward pressure.

B M at centre of beam =

$$\frac{w\,t}{2}\cdot\frac{l}{2} - \frac{w\,l}{2}\cdot\frac{t}{4}$$

$$= \frac{W_t\,.\,l}{4} - \frac{W_t}{8}\,.\,t$$

$$= \frac{W_t\,l}{4} - \frac{W_t}{8}\,(l + 1\tfrac{1}{2}\,n)$$

$$= \frac{W_t\,l}{4} - \frac{W_t}{8}\,.\,l - \frac{W_t}{8} \times \tfrac{3}{2}n$$

$$= \tfrac{2}{8}.\ W_t\,l - \tfrac{1}{8}\,W_t\,l - \tfrac{3}{16}W_t\,n$$

$$= \frac{W_t\,l}{8} - \tfrac{3}{16}W_t\,n \text{ (Eqn. No. XI.)}$$

Let W_t = 3 tons; l = 120 inches; n = 6 inches; t = 129 inches; l_c = 117 inches.

Then by Eqn. No. XI., maximum B M

$$= \frac{3 \text{ tons} \times 120 \text{ ins.}}{8} - \tfrac{3}{16} \times 3 \text{ tons} \times 6 \text{ ins.}$$

$$= 41{\cdot}625 \text{ ton-inches.}$$

Let us try $\frac{W\,l}{8}$ as a convenient approximation.

Here $w = \frac{3 \text{ tons}}{129 \text{ inches}} = \frac{3}{129}$ tons per inch run.

$$W = w\,l = \frac{3}{129} + 120$$

$$\frac{W.l}{8} = \frac{w\,l^2}{8} = \frac{3 \times 120}{129} \times \frac{120}{8}$$

$$= 41{\cdot}860 \text{ ton-inches.}$$

Other examples chosen at random will also show that the difference between

$$\frac{W.l}{8} \text{ and } \left[\frac{W_t\,l}{8} - \tfrac{3}{16}W_t\,n\right]$$

is practically negligible.

We see then, that for a straight joist freely supported, if the value of the effective span be inserted in our $\frac{w\,l^2}{8}$ formula, we shall obtain a very close approximation to the lengthier equation No. XI.

It may be profitably borne in mind that for an average joist without initial camber, and resting on average bearings, the effective span is probably not very different from $l_c + \frac{n}{2}$.

In the case of a joist resting on two other joists we should take the distance between the centres of the supporting joists as the effective span, because the flanges of the supporting joists would probably deflect under the load. (See Fig. No. 28.)

In the case of a joist resting on the lower

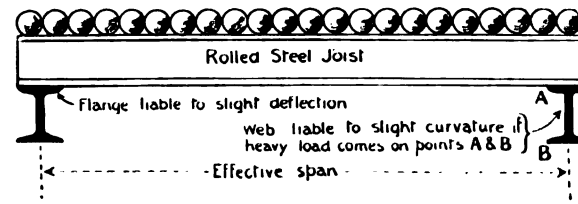
Rolled Steel Joist
Flange liable to slight deflection
A
Web liable to slight curvature if heavy load comes on points A & B
B
Effective span

FIG. 28.

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flanges, or fitting between the flanges, of two other joists, we err on the safe side when we take the pitch of the lower joists as the effective span.

In the case of floor joists built into the side walls, as shown in Fig. 29, we take the distance between the walls in our $\frac{W\,l}{8}$ formulæ,

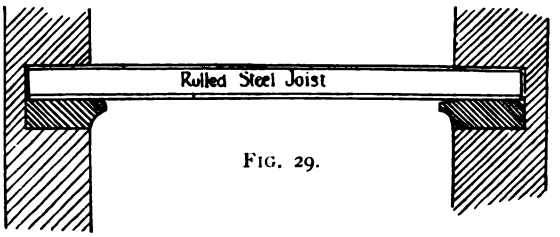

FIG. 29.

not because of the position of the reactions, but for other reasons. It is proved in advanced text-books that a beam will bear 50 per cent. greater load if both ends are firmly fixed. In floor joists, as a rule, this fixing of the ends is incomplete and inefficient, and frequently may increase the strength by no more than 5 or 6 per cent. Therefore it is not usual to make any great allowance for this increment. This, however, we do know, that when we take the bending moment, as $\frac{W\,l}{8}$ and insert the distance between the walls as the value of l, we are on the safe side, because of the fixity of the ends, which is not otherwise allowed for. In other words, the shortage of 2 or 3 per cent. due to our using the clear span instead of the distance between the centres of the supporting walls, is more than compensated by the additional strength due to the partial fixity of the ends.

The best value of l for use in the $\frac{W\,l}{8}$ formula has been definitely given.

Let us be agreed upon the best value for W.

Let B = the distance between the centres of consecutive floor joists in feet.

„ L = the distance between the walls, in feet.

„ C = the weight of the flooring + the load on the floor, in cwts. per square foot.

„ W_b = the total weight of one joist in cwts.

„ W_c = the total weight supported by each joist (in cwts.)

Then W_c = C.B.L. + W_b [Eqn. N°. XII.]

The weight of the wall above the floor level is not supported by the ends of the joist, for the wall would be entirely undisturbed if it were possible to cut the floor joist into three parts; letting the centre portion fall and withdrawing the two ends from their sockets in the wall. It is the bonding of the brickwork which prevents any of the dead weight of the wall being carried by the ends of the joist.

In Equation No. XII., W_b often proves to be very small in comparison with C.B.L. This is particularly the case with short spans and heavy loading.

In these cases W_b is usually neglected; and we take C.B.L. as the value of W in our $\frac{W\,l}{8}$ formula.

Another method is to allow something for W_b in taking out the weight of the floor. In this case, the total weight to be supported will be covered by the value of C.B.L.

The reader has now advanced step by step from the consideration of the effect of hanging a weight on the rim of a wheel to the effect of fixing the ends of a loaded girder.

This last point has been merely touched upon, and its fuller consideration must be reserved for a later paper. I have omitted the bending moments for cantilevers, such as beams projecting from a wall, and unsupported at the outer end.

I have done this because I am of opinion that cantilevers, although usually given first, are not so obviously illustrative of the fundamental principles as freely supported beams are.

The student can make a model of a freely supported beam with two spring-balances, a wooden rod, and a few weights; and can prove to his satisfaction that for any point whatsoever the algebraic sum of the turning moments of the loads and reactions is equal to zero.

To prove that this is true for a cantilever fixed in a brick or stone wall, and to take into account the variation of pressure on the brickwork, is a problem demanding greater previous knowledge on the part of the student.

Therefore, I take freely-supported beams first. I intend to return to cantilever problems as soon as the student is in a position to calculate the reactions within the wall, and the stresses within the projecting member.

Shearing Forces.—We have seen how the bending of beams produces certain internal stresses, and we must now consider

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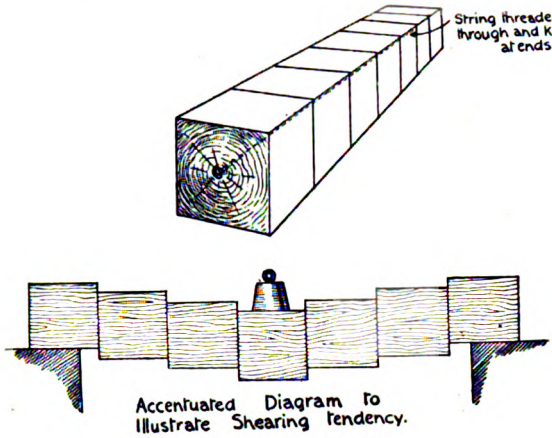

FIG. 30 (*a* AND *b*).

induced stresses of different nature prior to taking up moment of inertia problems.

Suppose a number of cubes of wood, with holes drilled through them, are fastened together, as in Fig. 30*a*. If this built-up beam is supported across a gap, the cubes will tend to slide past one another (see Fig. 30*b*.)

If these cubes were very tightly drawn together, the friction between the surfaces would keep them from slipping. There would still be the same tendency to slip, but it would be resisted. If the cubes were glued together there would be the same tendency for one cube to slide past its neighbour. If the cubes were now replaced by one continuous piece of wood, loaded and supported as in the previous cases, the tendency of consecutive vertical layers to slide past each other would be the same, but the internal resistance to sliding would be greater than in the previous cases.

This tendency of one part of a beam to slide past the adjacent part is called the shearing tendency. We can paraphrase this definition by saying that the algebraic sum of all the external forces on one side of any cross section of a beam is termed the shearing force across that section. The external forces acting on a beam are sometimes divided into two classes, loads and reactions. The loads are sometimes spoken of as the active forces, and the reactions are then called passive forces. They are spoken of as passive forces because they are only called into action by the active forces, and cease to exist so soon as the active forces are removed.

When we know the loads on a beam, we can find the reactions by taking moments around specified points. When we know the reactions we can find the shearing force which acts across any and every cross section. When we can find the shearing force we can draw a diagram which will picture vividly to our minds the shear at every part. Since action and reaction are equal in magnitude, but opposite in direction, it follows that if the left portion of a beam at any cross section tends to slide upwards relatively to the right, the right-hand portion will tend to slide downwards relatively to the left, and *vice versâ*. If this should not be clear at the first reading, turn back to any of the numerical examples of bending moments, and take any case where the loads and reactions are figured. Take a section through the beam at any point whatsoever, and consider the part of the beam to the left of the chosen section. Find the net upward or downward force (not the moments of the forces). Do the same for the right-hand portion and compare the results. Remember that the forces on one side of a section must be balanced by the forces in the opposite direction on the other side of the section.

Positive and Negative Shearing Forces.—It has already been stated that the terms *positive* and *negative* are employed to distinguish between opposite directions. It is usual to consider upward forces as positive, and downward forces as negative. It has been the custom of the writer to consider the forces on the left-hand side of any cross section, and if the resultant or algebraic sum is in an upward direction, to consider this as a positive shear.

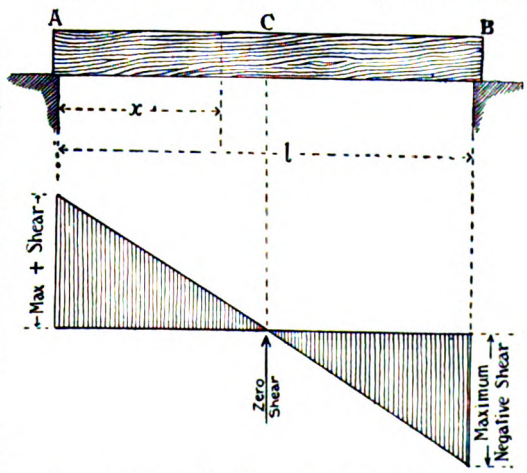

FIG. 31 (*a* AND *b*).—DIAGRAMS OF SHEARING FORCES DUE TO WEIGHT OF BEAM.

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In other words, there is a positive shear at any cross section when the left-hand portion tends to slide upwards relatively to the right. This custom is in keeping with our rule for positive and negative bending moments.

Let us now find the shearing forces at every section of a beam due to the weight of that beam. See Fig. 31 (a).

Let w = the weight of the beam in tons per foot run. Let W = the total weight of the beam, = $w\,l$.

Each reaction equals $\frac{w.l}{2} = \frac{W.}{2}$

The only upward force to the left of any section between A and B = $\frac{W.}{2}$

The total downward forces on any part of the beam to the left of any cross section between A and B = $w\,x$.

Because this force is downward, we prefix the minus sign. The total shearing force to the left of any cross section will then be equal to S, where

$$S = \frac{W}{2} - w\,x$$

$$= \frac{w\,l}{2} - w\,x.$$

If we take a base line representing the span of the beam to some convenient scale, and on this base line set up ordinates representing the value of S for every point along the beam, we shall obtain a shearing force diagram. Positive values of S should be set up above the base line, and negative values should be set down below the base line. The student should work out some numerical example for himself. Try W = 2 tons and l = 10 feet, and plot the value of S for points along the beam at intervals of a foot.

The student who has done this will be in a position to realise that S has a maximum positive value when x equals O, and a maximum negative value when $x = l$; and that the shear is zero when $x = \frac{l}{2}$.

For in this latter case

$$\frac{w\,l}{2} - w\,x = \frac{w\,l}{2} - w\,\frac{l}{2} = O.$$

Putting these equations into words, we say that the shear for a uniformly distributed load is a maximum at the reactions, and a minimum at the centre of the beam.

The student should prove, by numerical examples, that the form of the shearing force diagram is similar to Fig. 31 (*b*).

Shearing Force Diagram for Single Concentrated Load.—Refer to Fig. 32 (*a*). The shearing force for all sections to the left of B

$$= + 2 \text{ tons.}$$

The shearing force for all sections between B and C

$$= + 2 - 3 \text{ tons} = - 1 \text{ ton.}$$

The negative sign indicates that the left part of the beam tends to move downwards relatively to the right.

On a line representing the span of the beam, set up ordinates representing the value of the shear at the various sections. It will be seen that between A and B all the ordinates will be of the same height, and that for all sections between B and C the ordinates will also be of uniform height. See Fig. 32 (*b*). To the advanced student I might point out that this diagram is not based on a principle different from that employed in Fig. 31 (*b*), for in Fig. 32 (*b*) the shear between A and B

$$= R_L\,x^o$$

or alternatively S = $R_L \pm b\,x$ where b = *o*, and x equals the distance from the left reaction.

Similarly the shear between B and C

$$= (R_L - W) \pm b\,x$$

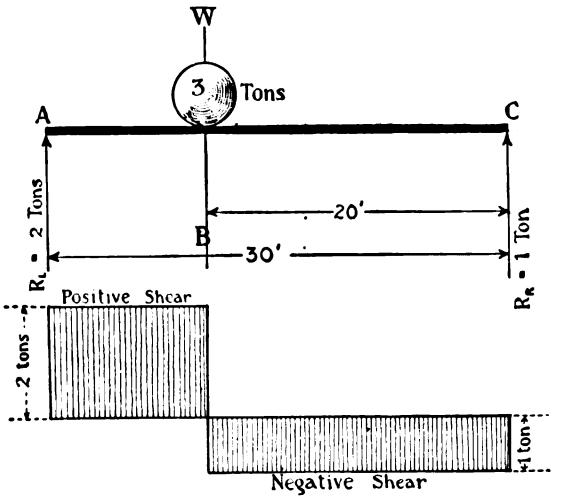

FIG. 32 (*a* AND *b*).

(*To be continued.*)

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WHY A NOSING MOTION IS REQUIRED ON THE SELF-ACTING MULE.

By WM. SCOTT TAGGART, M.I.Mech.E., Author of "Cotton-Spinning."

A COP represents the ultimate object of all the cotton spinning mills of the world. Its production is the completion of the first great step in transforming the fibres of the cotton plant into sewing cotton or cloth. The machine which makes the cop is called the Self-Acting Mule or "Self-Actor," and its mechanism is probably the most complicated of any single machine in the whole range of mechanics or engineering.

An interesting problem associated with the formation of a cop is that known as "nosing." An explanation of this problem may prove useful to those employed in the cotton spinning branch of the textile industry, and it is certainly a feature all cotton spinning students ought to carefully study.

Fig. 1 is a diagrammatic sketch of a mule cop. This cop is in construction continuous, but its formation consists really of two parts known as "the cop bottom" and "the body of the cop." The cop bottom is built, as it is termed, on the parallel part of a steel spindle, whilst the rest of the cop, called the body, is gradually built up around a tapered extension of the same spindle.

On referring to Fig. 1, the cop bottom is shown at A J G H K. Only three layers of yarn are marked, *viz.*, the first, middle and last layers. All further layers go to build the body of the cop until its completion, L N representing the last layer of the finished cop.

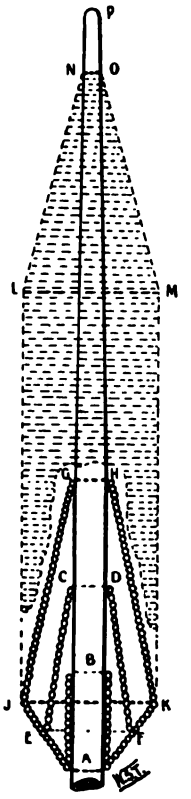

FIG. 1.

It will be noticed that the diameter of the spindle, when the last layer J G of the cop bottom is wound on, is larger than the diameter of the spindle when the last layer L N of the complete cop is wound on.

The problem to be solved is how to so cause the spindle to wind on the yarn that compensation will be made for the tapering of the spindle.

The necessity for a difference of speed in the spindle as the cop is built up may be shown by a simple calculation.

Suppose the diameter of the cop is $1\frac{1}{8}$ in. and the diameter of the spindle is $\frac{3}{8}$ in.; in other words, J K (Fig. 1) is $1\frac{1}{8}$ in. diameter and G H is $\frac{3}{8}$ ins. diameter. The yarn must be wound on this conical surface uniformly, *i.e.*, a certain length must be wound on in a given time, whether it is being guided on the larger or smaller diameter. The rate at which the spindle revolves to do this must vary with the layer. This varying speed is produced by a piece of mechanism known as the Quadrant. By calculation we find that one revolution of the spindle will wind on $1\frac{1}{8} \times 3{\cdot}1416 = 3\frac{1}{2}$ ins. of yarn on the large diameter J K. In the same way we find that the spindle, to wind on $3\frac{1}{2}$ ins. of yarn at the small diameter G H must revolve $\frac{3\frac{1}{2}}{\frac{3}{8} \times 3{\cdot}1416} = 3$ times. In other words, the speed of spindle must gradually decrease as the conical layer is wound on from G to J until at J it is only one-third the speed of what it was at G. The Quadrant produces this variation.

If we now take the last layer L N of the cop and calculate the rate of the speeds of spindle required to wind on the yarn as we did the layer J G, we shall find the ratio between the two extreme speeds to be different. The diameter L M is the same as J K, *viz.*, $1\frac{1}{8}$ in.; but owing to the tapering of the spindle, the diameter at N O is only $\frac{1}{8}$ in.; the speed at L M may be unity and will wind on $3\frac{1}{2}$ ins. as before; but at N O this $3\frac{1}{2}$ ins. will require $\frac{3\frac{1}{2}}{\frac{1}{8} \times 3{\cdot}1416} = 9$ revolutions.

From this we see that the rate at N O is

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nine times quicker than at L M, and it also shows us that when winding on at N O the spindle must have a rate of speed three times quicker than when winding at G H.

Now the Quadrant cannot, by itself, vary the already varying speed which enables the spindle to wind on the conical layer J G, so the necessary additional variation of speed as the cop body is built must be given, either by the manual help of the winder or by an additional piece of automatic mechanism. Such a piece of mechanism is termed a *nosing motion*.

A graphic method of representing the varying speed of spindle to compensate for the tapering spindle is shown in Figs. 2 and 3. The curves drawn in Fig. 3 are based on the dimensions of the diagram of the cop in Fig. 2; these dimensions are not the same as the cop in Fig. 1, being exaggerated in order to more fully explain the principle. Although this graphic method is much the better of the two as an explanation, it is only those students who have some knowledge of geometry that will thoroughly understand it. Its simplicity lies in the fact that very little calculation is necessary, and yet it produces results that convey in a glance the whole variation and its necessity.

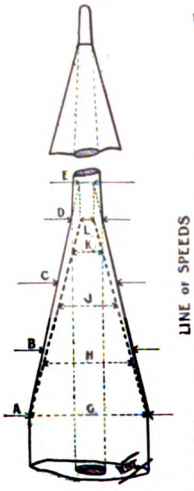

FIG. 2.

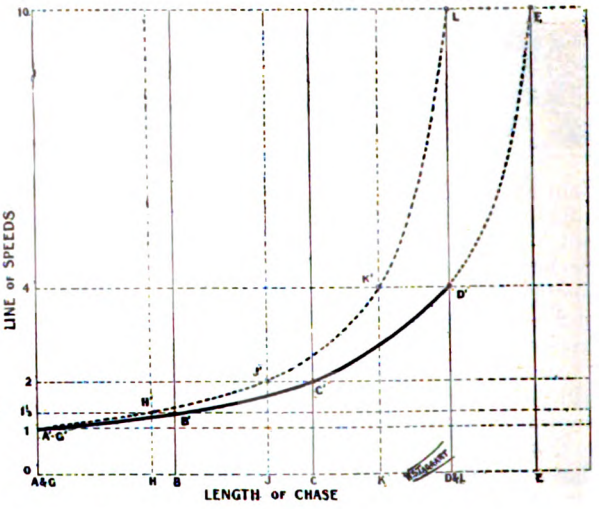

FIG. 3.

In Fig. 2 the line A D represents the chase or inclined surface of the last layer of the cop bottom. A L similarly shows the chase of the last layer of the cop body. By drawing them together one can see at a glance the difference in inclination due to the difference of diameter at the "nose" of the cop, as the top of the layer is termed. By plotting curves in Fig. 3, obtained from the dividing lines in Fig. 2, we obtain the full line curve representing the varying speed for the last layer of cop bottom, and the dotted curve gives us in a graphic form the variation of speed required for the last layer of the cop body. A glance shows us that one set of varying speeds is not the same as the other set. Between the extreme sets there is a constant variation in speed taking place whilst the cop is building.

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ELECTRO-CHEMICAL AND ELECTRO-METALLURGICAL INDUSTRIES.

PART II.—COPPER.

By JOHN B. C. KERSHAW, F.I.C.

THE use of electricity in the copper industry has attained its greatest development in connection with refining operations; the electrical processes for the production of tubes and other hollow articles, and the electrolytic extraction processes, not having been so successful as their inventors and promoters at one time hoped. In the following pages, the writer will deal chiefly with the electrolytic copper refining industry, which has attained enormous proportions; and, more briefly, with the Dumoulin and Elmore processes for producing copper tubes by electro-deposition, and with the various processes in which electricity is employed for extracting copper from its ores. Electro-typing, or the production of copper blocks for printing purposes, is a special branch of the electrical copper industry; and to describe adequately the marvellous strides which have been made in this minor industry would require more space than the writer has at his command. Electro-typing will not, therefore, be specially dealt with in this article: it must suffice to state that every large and up-to-date printing office is equipped with electro-typing plant; and that the time required to make blocks fit for use in the printing machines has been reduced from hours to minutes, by the utilisation of improved methods of working the depositing process.

Introduction

I.—Copper Refining.

The use of electricity for refining copper and other metals was first suggested by Charles Watt, in his remarkable Patent, No. 13,755, of 1851. This patent contains the germ of nearly all the modern industrial developments of electrolysis; the production of alkalies, of hypochlorites, of chlorates, and of pure metals, all being described by Watt in Patent No. 13,755, which one may certainly regard as the master-patent of the electro-chemical and electro-metallurgical industries. Unfortunately, Watt was at least forty years too early with his proposals and schemes for utilising electrical energy; and, until the dynamo had been greatly improved, there was no source from which sufficiently large currents could be obtained for chemical and metallurgical operations. No industrial developments, therefore, followed the publication of Watt's patent, and it was left for James Elkington, of the famous Birmingham firm of electro-platers, to carry out Watt's proposals in practical form, as regards the electrolytic refining of copper. Elkington patented his process in the years 1865 and 1869, and in the latter year the process was put into operation, on a small scale, at Pembrey, near Swansea, in South Wales. The process and plant proving successful, the works were enlarged; and it is an interesting fact that although this first electrolytic copper refinery has changed hands, and no longer belongs to the Elkington firm, it is still in existence, and is still producing copper by the process introduced there by James Elkington thirty-five years ago.

Historical Notes

In the period 1870-1890, the growth of the industry was slow; and though several electrolytic copper refineries were erected in England, France, Germany and America, their sizes were small, and the total output of electrolytic copper in the year 1891 was estimated only at 30,000 tons. Since 1891, however, the industry has undergone enormous expansion, chiefly in America; and at the present date there are, according to T. Ulke, the statistician of the industry, 32 electrolytic copper refineries in operation, with an annual output of over 320,000 tons of copper. Since the total world's production of copper is now about 540,000 tons per year, these figures show that 60 per cent. of the raw copper produced is submitted to the electrolytic refining process. This remarkable development of what, down to 1886, was a comparatively small industry, is due to the great demand for copper for electrical purposes; the presence of even minute amounts of impurity having a marked effect upon the conductivity of the metal. The ordinary metallurgical methods

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of refining copper cannot remove the silver, antimony, and gold which are present in the raw copper, so effectually as the electrical method; hence the success of the electrolytic refining process, and the extraordinary expansion of the industry in recent years. It is noteworthy that the growth of the industry has occurred chiefly in America; and Ulke, in his most recent publications, gives the following figures for the number and proportionate output of the refineries in the various countries of the world:—

	Refineries.	Proportionate Output.
United States	9	86·50 per cent.
Germany	9	2·75 ,,
United Kingdom	6	8·80 ,,
France	4	1·60 ,,
Russia	2	·35 ,,
Austria-Hungary	2	
	32	100·00

THE ELECTRICAL COPPER COMPANY'S WORKS, WIDNES.
VIEW III.—THE DEPOSITING TANKS, WITH ELECTRIC CRANE.

The reasons for this great development of the copper refining industry in America, where it was introduced at a much later date than in Europe, will be dealt with under the next heading; but it may be stated here that it is not lack of scientific knowledge on the part of European refiners that has led to this transfer across the Atlantic of the chief centre of the industry from England and Germany.

The Refining Process

When an electric current is passed through a slightly acid solution of copper sulphate, using two flat pieces of pure copper as electrodes, copper passes into solution at the anode, and is deposited at the cathode. The electrolyte itself shows no sign of change during this passage of atoms of copper from the anode to the cathode. If the electrodes are weighed before and after the experiment, it will be found that the weight of copper deposited at the cathode equals the weight lost by the anode.

If raw copper (as, for example, that known in the trade as *blister or converter copper*) containing from 2 to 4 per cent. of impurities, be substituted for the pure metal as anode material in this experiment, the same action occurs. In this case, however, the impurities of the copper (which usually comprise silver, antimony, and gold) do not pass into solution, but remain as a finely divided deposit on the face of the anode, and ultimately fall to the bottom of the cell. At the end of the experiment, it will be found that the copper deposited on the cathode is less in weight than the metal removed from the anode. Only a small E.M.F. of about 0·12 volt is required to carry out this transfer of copper from anode to cathode, because the back E.M.F. due to the deposition of copper at the cathode is nearly balanced by the direct E.M.F. due to the solution of copper at the anode.

The electro-chemical principles revealed by this simple laboratory experiment form the basis of the electrolytic copper refining process, as patented by James Elkington in 1865; and few alterations in the working details of the process have been made since it was first operated at Pembrey in 1869. The plants have, of course, been enormously increased in size; and, with larger vats, and improved mechanical arrangements for casting and moving the heavy plates of crude copper used as anodes, the working costs of the process have been greatly reduced; but in its main features the electrolytic refining process, as operated to-

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day, is practically that introduced by Elkington 35 years ago. The chief changes have been in the size and construction of the cells or vats. At Pembrey, cylindrical earthenware vessels, 33 inches in height by 17 inches in diameter, were originally employed; and each of these cells contained 10 electrodes—namely 4 cathodes and 6 anodes. One hundred of these earthenware cells were placed in series in terrace-wise fashion, so that circulation of the electrolyte could occur

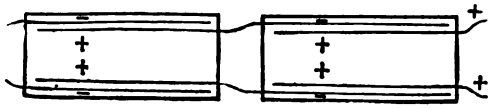

FIG. 1.—THE *THOFERN*, OR PARALLEL SYSTEM OF CONNECTION IN COPPER REFINING.

by the aid of syphons through the whole number. The electrodes of each vat were connected in parallel; the vats, in series. In the early days of the industry, the output of copper at Pembrey was only 15 cwts. per 24 hours, or about 250 tons per annum. The earthenware cells soon gave place to large rectangular wooden tanks, and the number of electrodes was increased from 10 to 40 or more per vat; while the weight of each anode plate was raised to 2 cwts. The number of vats worked in series was also greatly increased, since it was found to be more economical to use dynamos generating current at a comparatively high E.M.F.

As regards the arrangement of the electrodes in the vats, the parallel arrangement originally introduced at Pembrey is that which still finds most favour. The plan of this arrangement, for two vats, is shown diagrammatically in Fig. 1, the electrodes being left out, in order to show the current conductors, or "bus bars," more clearly. The electrodes are plates from $\frac{1}{16}$ up to 2 inches thick, cast in the form shown in Fig. 2, with projecting ears or lugs. And by making these lugs rather longer in the case of the cathodes, connection is made with the negative, or outer, bus-bar, the level of which is raised a little above that of the inner, or positive bus-bar, which carries the anodes. The vat is filled with anode and cathode plates, arranged alternately, only $\frac{3}{4}$ inch of space separating each pair; and a fully charged vat, of modern construction, will therefore hold several tons of anode plates.

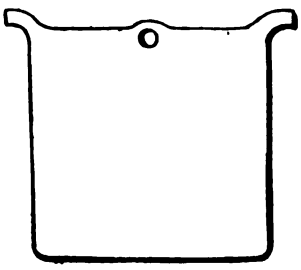

FIG. 2.
FORM OF ELECTRODE USED IN COPPER REFINING.

The cathode plates are thin sheets of pure copper, rather larger in superficial area than the anodes; and in large refineries, a special section of the plant is devoted to producing these thin sheets, by electro-deposition on specially prepared forms, from which they are stripped when sufficiently thick. The parallel system of electrode arrangement just described is known as the *multiple*, and also as the *Thofern* system.

Another arrangement of electrodes which is used in a few American refineries is that known as the *series* or *Hayden* system. Fig. 3 is a diagrammatic plan of a vat, filled with electrodes arranged on this system. Only the two end electrodes are connected to the main current conductors; all the intervening electrodes are what is technically termed "*secondary*" electrodes, and are insulated from the vat and from each other. The result is that the current has to travel through the whole length of the vat without passing outside the electrodes; and each of the intervening plates, therefore, functions on one side as a cathode, and on the other as an anode, as shown by the + and − signs in the diagram. It is obvious that specially

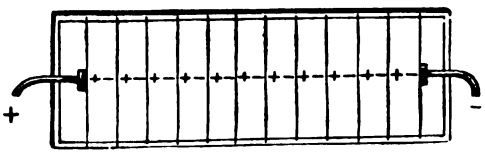

FIG. 3.—THE *HAYDEN*, OR SERIES SYSTEM OF CONNECTION IN COPPER REFINING.

prepared anodes must be employed for this system, as it is requisite to strip off the deposited copper from the electrode, when the latter is withdrawn from the vat. The first cost of preparing anodes in the refineries working the series system is, therefore, higher than with the parallel system of electrode arrangement; but in spite of this fact, the "series" or "Hayden" system is still used in America, and it has recently been adopted for a new refining plant.

The impurities of the raw copper which collect in both systems, on the floors of the vats, are known as "slimes," and are removed from the electrolyte by filtration. After pressing the mud into cakes, and drying, these are sent to the bullion works for extraction of the gold and silver which they contain. It is the presence of

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these valuable metals in the slimes which has led to such a rapid growth of the copper refining industry in America.

American copper ores are pyritic in character, and carry much larger amounts of silver and gold than the copper ores mined in Europe. Ulke has recently estimated that 27,000,000 oz. of silver and 346,020 oz. of gold are annually recovered from these "slimes" in America; and the annual value of the recovered "impurities" of the raw copper in that country is therefore close upon £4,000,000.

The absence of these valuable constituents, in like amount, in European copper ore, is the chief reason why the European refining industry, though older, has shown less vitality and expansion.

Limits of space will only allow a few details to be given of the refining plants at three typical refineries in Europe and America.

Description of Three Typical Refineries

The largest English refinery is that of Messrs. Bolton and Sons, at Froghall in Staffordshire. The depositing vats at this refinery number 550, each vat measuring 48 inches by 30 inches by 42 inches deep. When fully charged, each contains 10 anodes and 9 cathodes. The E.M.F. of the current employed for each series of vats varies from 35 to 50 volts, according to the number of vats connected together in series; and the generating plant at this works is rated at 600 K.W. The same firm has a second refinery at Widnes, in Lancashire, and here 300 K.W. are employed in the process. The two refineries are worked on the "multiple" system of electrical arrangement, and when fully employed can produce 10,000 tons of refined copper per annum.

The most notable electrolytic copper refineries are, however, to be found across the Atlantic, one of the largest being that of the Anaconda Copper Mining Company, situated in the Butte district of California. This refinery is run by steam-power, and the generating plant comprises 7 dynamos, each generating 4,000 amperes at 60 volts. The aggregate power of the generating machinery is therefore 1,680 K.W. or 2,800-horse-power.

The depositing tanks number 1,400, each tank being 8 feet in length, by 4 feet wide by 4 feet deep, and constructed of 3-inch planks lined with sheet lead. A tank, when fully charged, contains 76 anodes and 80 cathodes. Each anode measures 24 inches by 32 inches, by $1\frac{1}{4}$ inch thick. The weight of an anode is about 230 lbs., and a fully charged tank, therefore, contains over $7\frac{1}{2}$ tons of raw copper. Assuming that 1,200 depositing tanks are kept constantly in operation, fully 9,000 tons of copper are present in the vats at Anaconda, and at present market prices this copper represents a capital of £450,000. This calculation shows that electrolytic copper refining, as practised in America, demands an enormous capital outlay for plant and stock, and explains why the industry was chiefly in the hands of the great copper mining companies recently absorbed by the Amalgamated Copper Company.

The Anaconda refining plant is worked on the parallel or "multiple" system as regards electrode arrangement: 200 vats are worked in series, with a terminal E.M.F. of 60 volts, and a current density of 10 amperes per square foot of cathode area. The E.M.F. required per pair of electrodes is thus about 0·30 volt.

The Great Falls Refinery of the Boston and Montana Copper Company is situated in the same district, but is run by aid of water-power, and is worked upon the series or "Hayden" system of electrode arrangement. The generating machinery comprises two dynamos, generating, when running together, a direct current of 9,000 amperes at 200 volts. The capacity of the plant is, therefore, 1,800 K.W. or 2,960-horse-power.

The depositing tanks at Great Falls number 312, and each is $9\frac{3}{4}$ ft. in length, by $2\frac{1}{3}$ ft. in width, by $3\frac{3}{4}$ ft. in depth. Each tank contains 20 anodes and 20 cathodes, arranged as shown in Fig. 3. The anodes are much thicker than those used at Anaconda, being $2\frac{1}{2}$ to 3 in., and one of these anode plates weighs no less than 632 lbs. on being charged into the vat. A fully charged vat at Great Falls, therefore, contains 5·6 tons of copper, and as the current density employed is four times that used at Anaconda, or 40 amperes per square foot of cathode area, the corrosion of the anodes is completed in 18 days, as compared with 37 days at Anaconda.

At Great Falls, the tanks are worked in three sets of 104 each, and the E.M.F. per pair of electrodes is 0·60 volt.

The raw copper used in these two refineries is practically the same in composition, since it is obtained from the famous mines of the Butte district, and contains 98 to 99 per cent. copper, with 40 to 120 oz. silver, and from 0·10 to 1·50 oz. of gold per ton.

The refined copper contains 99·96 per cent. Cu., with traces of arsenic, antimony and silver.*

* These details are chiefly drawn from a paper by Hofman, read before the American Institute of Mining Engineers in 1903.

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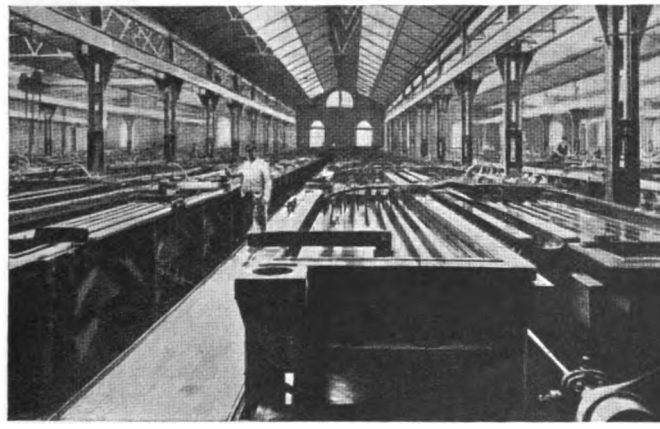
The Raritan Copper Refinery at Perth-Amboy is the largest of the remaining plants in U.S.A. According to Ulke, it now has an output of 150 tons of refined copper per day, equal to 45,000 tons per year of 300 working days.

Costs of Refining Copper by Electrolysis

In America the costs of refining copper by the electrolytic process have been greatly reduced in recent years, by the increase in the size of the refining plants, and by the introduction of labour-saving appliances. All the more modern refineries on the other side of the Atlantic are now provided with travelling cranes in the depositing vat houses, for charging and removing the anode and cathode plates; and the latest form in which these are designed permits the whole set of anode and cathode plates to be charged into, or removed from the vat in one operation.



THE WORKS OF THE ELMORE COMPANY, HUNSLET, LEEDS.
THE DEPOSITING TANKS.

Casting machines are also now being employed for making the anode plates, and here again a great saving in labour costs has been achieved.

In the earlier days of the industry, Peters and Ulke estimated the cost of refining copper by the electrolytic process in America as lying between 33*s.* 4*d.* and 64*s.* per ton of refined copper, no allowance being made in these estimates for the value of the recovered gold and silver. It is probable that these costs have been reduced quite 30 per cent. by the modern labour-saving appliances, and as raw copper is stated to be now accepted for refining in U.S.A. at a charge of 40*s.* per ton, the margin for profit to the refineries must still be very high. There are no recent and trustworthy figures available relating to the corresponding costs in Europe, but as the English, French and German refineries are mostly small in size, and operated entirely by hand labour, the refining costs are probably higher than in America.

As regards the value of the recovered "impurities" of the raw copper, this varies considerably with the different classes of ore. The copper ores of the Butte district are some of the most valuable in this respect, and at Anaconda and Great Falls, according to the figures given by Hofman, the value of the recovered silver and gold per ton of refined copper may rise as high as £10 : 10 : 0. The average value of the "impurities" of the ores of this district is, however, much below this maximum, and may be taken at £6 : 10 : 0 per ton of refined copper. If the refiners were allowed to sell their slimes, or the recovered gold and silver, the electrolytic treatment of the Butte raw copper would be a very profitable operation, even without any payment; but it is usual for the mining company to retain their interest in these "impurities," and to simply pay a fixed charge per ton for the refining process, when this is worked by an independent company.

As already stated in the introduction to this article, the copper ores mined in Europe are comparatively poor in their contents of gold and silver, and consequently the crude copper does not in all cases pay for electrolytic refining.

Utilisation

The enormous development of the electrolytic refining industry in recent years has been chiefly due to the demand for copper for electrical purposes; and the growth of the refining industry has consequently been an index of the development of the electrical engineering industry.

The figures given in the introduction, for the output of electrolytic copper in various years, show that this expansion of the industry dates from 1886, and that it still continues.

It is a remarkable fact, and one that is still unexplained by physicists, that although silver has a higher electrical conductivity than copper, a few grains of silver distributed through the mass of a ton of copper increase the electrical resistance and diminish the

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conductivity of the latter.* Other metals and elements act even more detrimentally upon the electrical conductivity of copper, and hence it is, that copper of the very highest purity is demanded for electrical engineering work. The standard of conductivity is 100 by Mathiessen's scale; but owing to the fact that the copper assumed to be pure when Mathiessen carried out his experiments, contained small amounts of impurity, it is no unusual thing for copper to be sold for electrical purposes at the present day, testing 101, 102, or 103 by Mathiessen's standard.

The electrolytic copper refining industry, in one aspect, is a unique industry, for electricity not only supplies the energy, but the applications of electricity in the arts and industries provide the market for the copper produced.

II.—The Elmore and Dumoulin Processes.

The copper obtained on the cathode sheets in the electrolytic refineries, owing to the rapid rate of deposition adopted, is coarse and crystalline in structure, and the sheets require melting before they can be used for drawing into wire, or for other purposes. Elmore was one of the first to attempt to combine the refining operation with the production of copper at the cathode in form suitable for immediate use, and a very large number of patents has been taken out in his name in the period 1894–1900, relating to a process for producing tubes and other hollow articles of copper, directly, in the electrolytic vat. The fundamental idea of his process is the utilisation of a revolving shaft, or "mandrel," for reception of the deposited copper, this mandrel being immersed in the electrolyte, and connected to the negative supply terminals.

In order to permit of comparatively rapid deposition without decreasing the fineness or density of the deposit, Elmore also arranged for agate burnishers to continually travel over the length of the revolving cathode, and in this way he obtained tough and fairly dense deposits of copper upon the mandrel in 20 or 30 days. At the end of this time, the mandrel could be withdrawn, leaving a hollow seamless tube of copper of very high purity.

The industrial development of the Elmore patents, from which great things were expected, has unfortunately been much hampered by technical difficulties in working the process on a large scale, and by financial troubles. At the present date, there are three Elmore copper works in operation—one at Hunslet near Leeds; one at Dives in France; and one at Schladern in Germany. Of these, the French and German works have been most successful, and modifications in the original process are said to have been introduced at Schladern for the production of tubes of small diameter without any drawing down operation, which materially reduces the cost of manufacture. The plant of the English Elmore Company, at Hunslet near Leeds, has also recently been overhauled and re-arranged; so possibly the various Elmore companies may have, at last, entered upon a more profitable stage of their existence.

The Dumoulin process is a second process for producing tubes or sheets of copper by electro-deposition, which has attained industrial trial in this country and in France. In principle this process closely resembled the Elmore process, but strips of sheepskin replaced the agate burnishers of the latter process, and the surface friction produced by these, as the mandrel revolved, gives the necessary adhesion and closeness of texture to the cathodic deposit of copper. Fig. 4 shows a diagrammatic section and elevation of the Dumoulin vat.

Mandrels of any size may be used for the Dumoulin process; and when sheets of copper are required, tubes 16 inches in diameter may be first produced, and these may be cut open to form large sheets.

The Dumoulin process was protected by French and English patents taken out in 1895, 1896, 1897; and after preliminary trials of the process in Paris, a company was formed in 1897 to work the Dumoulin patents in this country. This company was named "*The Electrical Copper Company*," its nominal capital was £500,000, and works utilising 800-horse-power were erected at Widnes, in Lancashire. The writer visited the plant in August, 1898, and saw the process in operation on a large scale, copper sheets being then the chief product.

From various causes, chiefly financial, the works were not a success, and in 1901 the Directors decided to shut down the plant and to sell the patents, and all the other available assets of the company.

The Dumoulin process is, therefore, no longer industrially operated in this country; and it is probable that the experimental plant in Paris has also been stopped, though upon this point the writer has no trustworthy information at his command.

III.—Electrolytic Extraction Processes.

A very large number of patents relating to the extraction of copper from its ores by aid

* Compare Professor Barrett's article, February TECHNICS, pp. 124-125.

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of electrolysis have been taken out during the last twenty years, but a detailed account of the experimental and industrial trials of even the more important of these processes would demand an article in itself. The majority of such extraction processes have depended upon the use of a solvent for dissolving the copper from the crushed and roasted ore, this operation being usually carried out in special *leaching* vats. The solution of copper obtained in this way was then electrolysed in specially designed depositing vats, with insoluble anodes and cathodes of pure copper. Only in a few cases was it proposed to use the copper ore, or matte, directly as anode material in the depositing vats. Most of these processes have failed to attain permanent success, although in some cases large sums of money have been sunk in carrying out industrial trials upon an extended scale. The great difficulty has been due to the fact that the solutions obtained by leaching copper ores always contain certain impurities, and the gradual accumulation of these impurities in the electrolyte leads to irregularities and troubles in the depositing vats.

Only two processes of the above character are, so far as the writer is aware, in operation to-day, and these will be briefly described.

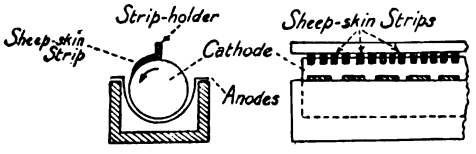

FIG. 4.—TRANSVERSE SECTION, AND SIDE ELEVATION OF DUMOULIN VAT.

The Hoepfner Extraction Process

The Hoepfner process is operated in Germany, and depends upon the use of a mixture of cupric and calcium chloride as leaching solution. Ore containing both copper and nickel is usually operated upon, and the copper is, therefore, obtained in the form of *cuprous chloride*. The electrolyte is reported to contain 65 grams of copper, and 80 grams of nickel per litre, in the form of chlorides; and before electrolysis it is submitted to a chemical treatment which removes the iron, nickel, lead, and silver.

The copper is then deposited by electrolysis in the usual manner, and the solution of cupric chloride which remains is again used for the leaching operation upon a fresh quantity of ore.

The process may also be worked with ores containing only copper; and with Rio Tinto ore carrying 3 to 4 per cent. Cu., good results are said to have been obtained in Germany.

The Hoepfner process has received trial upon an industrial scale at Giessen, at Wildenau, and at Papenberg in Germany; but, at the present date, it is only operated at the latter place.

The Carmichael Extraction Process.

The Carmichael process is an American process which has been worked upon an industrial scale at Dorchester, N.B., Canada, for some months in 1903. In this case a dilute solution of sulphuric acid is used as the leaching agent, and this operation is carried out upon the hot ore in large 20-ton vats, lined with lead, direct as it comes from the roasting furnaces. The ore used at Dorchester carries only from 2 to 4 per cent. Cu., and this percentage is reduced to 0·10 per cent. after the leaching operation.

The solution obtained from the leaching vats contains 2·5 per cent. Cu. and much free acid. The depositing vats are provided with anodes and cathodes of lead, and are arranged in cascade fashion. The cathodes are greased and covered with graphite powder, to promote the easy removal of the deposit of copper.

The electrolysis of the solution is stopped when the copper contents of the electrolyte have been reduced to 1 per cent., and the solution, which contains all the original free acid, is then again used for leaching fresh ore. The use of sulphurous acid gas in the depositing vats, for diminishing the polarisation of the electrodes, and for promoting circulation of the electrolyte, is an important feature of the Carmichael process.

As already stated, the process has been operated in America for some months, and an output of one ton of copper per day has been attained. The cost of working the process is stated by the inventor to be about 15*s*. per ton; but it is yet too early to regard the process as beyond its experimental stage of development. Neither the Hoepfner nor the Carmichael process can be considered to have solved the problem presented by the electrolytic extraction of copper from its ores.

IV.—Electro-metallurgical Concentration Processes.

Recently, considerable attention has been directed towards the possibilities of the electric furnace in connection with the smelting of copper ores; and during 1903 trials of this description, upon an extended scale, have been carried out at La Praz and other places in France, with Chilian ore, under the direc-

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tion of M. Vattier, an agent of the Chilian Government. The principle of this method of treatment is to submit the ore, as mined, to the high temperature attained in the electric furnaces, and to obtain in this way a concentrated "matte," which can then be treated further by the ordinary metallurgical processes of reduction. The process is, therefore, one of electric *concentration*, rather than an extraction process. The trials of 1903 in France have shown that it is possible to increase the percentage of copper from 7 per cent. up to 45 per cent. by this method of concentration, without any great loss in the slags which are produced; and it is therefore expected that there will be a great future for the process, in countries where fuel is costly and water-power (for generating the electric current) is plentiful. In Chili, where the process is shortly to be tried upon a more extended scale, coke is said to cost £4 per ton, and the cost of smelting copper ore, by the usual metallurgical methods, is reported to amount to nearly £13 per ton of copper produced. The estimated cost in that country, when using electricity for the preliminary concentrating process, is only £3 6*s*. per ton. If these figures are supported by the results of the trials which will shortly be made there, the success of the electric-furnace method of treatment would appear to be assured in Chili, and also in other countries possessing mines of low grade copper ore and abundant water-power.

SOME LABORATORY USES FOR ALUMINIUM.

By EDWIN EDSER, A.R.C.S.

N the laboratory it is frequently necessary to permanently mark glass vessels, either with graduations or with letters, etc. It is not so generally known as it should be that if aluminium be rubbed on glass it leaves a metallic streak behind. Pyknometers and certain forms of dilatometers may readily be marked in this manner; aluminium graduations on delicate glass tubes can easily be made, and offer the advantage that they do not produce weakness, as file or diamond scratches would. It is possible that lantern slides could be drawn on glass by the aid of the aluminium pencil. To mark glass with aluminium, it is only necessary to wet the glass and draw the pointed end of an aluminium rod firmly across it. In marking tubes with transverse graduations, the edge of a small sheet of aluminium may be conveniently used. It is necessary, however, to remember that aluminium is rapidly dissolved by alkaline solutions.

High resistances, comparable with a megohm, are somewhat costly to purchase. Many years ago it was proposed to draw a streak on the surface of ground glass by the aid of a lead-pencil, and to use this streak as a high resistance. Such a resistance, however, is far too inconstant to be of any practical use. The reason appears to be that particles of graphitic-carbon are left in the depressions of the ground glass surface, and these are liable to be shaken off, or to break contact one with another. A very serviceable megohm resistance can be made by drawing an aluminium streak on a *polished* glass surface. At each end of the streak a patch of aluminium may be formed, and if copper is deposited on these patches, connecting wires can, with care, be soldered to them by the aid of ordinary solder to which a sufficient amount of bismuth has been added.

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SURFACE CONTACT SYSTEMS OF ELECTRIC TRACTION.

By FRANCIS H. DAVIES.

THE surface contact system of electric traction offers so many possibilities in the way of superseding the trolley wire, and incidentally making an odd fortune or two, that it is not surprising that so many men, eminent and otherwise, have devoted their energies towards making it a commercial and engineering success.

That this has not yet been effected is an undoubted fact; whether from inherent bad qualities in the system, wrongly worked-out details, or unreasoning prejudice, is a matter of opinion. The surface contact enthusiast adheres to the latter cause; but looking at it from a bystander's point of view, all three appear to have had something to do with its want of success.

Mr. Philip Dawson, in a paper read at Nottingham in 1902, sums up the disadvantages of this system in the following words: "There is always a possibility that one of the automatic switches may fail to act, with the result that a stud will be left energised after the car has passed."

"The studs must project to a certain distance above the level of the road, or else the collector on the car will not make contact without rubbing on the road, hence the studs must always offer some obstruction to ordinary traffic."

"There is considerable loss through leakage from the studs."

The first of these objections is the real trouble; the second is truly an objection, but not nearly so important as the first; and the third, many firms at the present day claim to have entirely got over. The construction of a thoroughly trustworthy switch is what the whole thing turns upon; such switches have been invented and patented in multitudes, and anyone who has searched through the Patent Office records cannot have failed to have been struck with the ingenuity of many of the ideas.

The systems selected from this great mass of available matter, for description in this article, are all typical either of early or modern practice in surface contact traction; and according to their characteristics, are divided into three fundamental classes, according as the passing car acts upon the automatic switches (1) magnetically, (2) electrically, (3) mechanically.

Magnetic Systems.

Before going into these or other methods, it is necessary to explain that surface contact traction, as we know it, has been evolved rather than invented. Under the name of the *sectional rail system*, it was originally suggested as a means for reducing the tremendous leakage that, it was feared, would result in third rail electric railways from the great length of the current-carrying rail that would always be alive; and it provided, by various means, for the energising of only that portion of the conductor directly under the train. When the system was thought of in connection with street tramway work, it was seen that for obvious reasons a third sectional rail would be undesirable, and studs were therefore substituted in the road, and a skate collector on the car, the length of the collector being rather greater than the distance between two adjacent studs.

Fig. 1, copied from Pollak & Binswanger's patent specification of 1886, represents a very simple sectional rail system of the

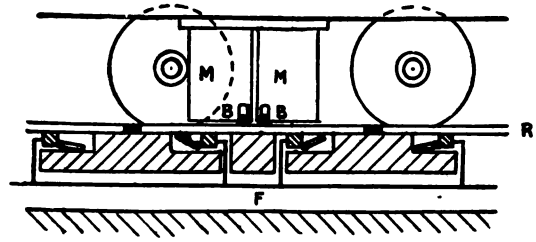

FIG. 1.—POLLAK AND BINSWANGER (1886).

magnetic type. Underneath the car was to be suspended a powerful electro magnet MM, running as close as possible to the collecting rail R, and energised either by the series or a shunt current. Under the rail in little chambers, two to each section as shown, were to be hinged pieces of iron, each connected to the adjacent feeder cable F. Two brushes BB, with a distance between them equal to, or greater than the length of the section

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insulator, were fixed in a central position near the magnet; and, rubbing on the rail, picked up the current. When the magnet came over one of the hinged pieces of iron, it naturally attracted it to the iron section rail, and being in direct communication with the feeder, thus made the latter alive. Directly the magnets passed, the hinged pieces fell down, and so cut off the current.

The practical objections to such a system are obvious. It would not work at high speeds, as the necessarily heavy hinged pieces would not have time to rise. In time the hinges would most probably stick, either in the up or down position; and the contact between them and the rail would be obviously very weak.

Altogether it requires but very little experience to see that such a system, ingenious and simple though it may be, would never work in practice; and the same may be said of many other early methods that need not be described here.

On the other hand, coming to more modern times, one of the latest developments in this branch, the Dolter system, has some very interesting features, such that it may be classed among the few that are decidedly practicable in appearance.

It is extremely simple, as may be gathered from Fig. 2.

The collecting and magnetic arrangements carried on the car—as in some other systems that a powerful magnetic field is constantly maintained between them; and this, when the bars reach a stud, passes through the hinged lever of the switch, attracting it upward and closing the circuit.

A noteworthy feature is the excitation of the magnets by the series current of the motors, in parallel with a small battery of four cells. This is a very ingenious arrangement, and a decided advance upon anything that has been previously described. The objection to series excitation of the magnets is that the field is constantly varying in strength, at one time actuating the switches with too great a force, and at another becoming too weak to move them at all.

In the Dolter system, however, this is obviated; the four cells that are used are always in parallel across the terminals of the windings; consequently when the series current falls, so reducing the P D between the ends of the coils, the cells discharge sufficiently to keep the current at its proper value; arrangements being made that when the motor current is completely cut off the cells will, unaided, excite the magnets to the requisite degree. Conversely, when the motor current reaches its maximum it will charge the cells, which by these means are always kept automatically in full working order.

The two small skates shown in the diagram to the left and right of the main collector are not peculiar to this method, being used in

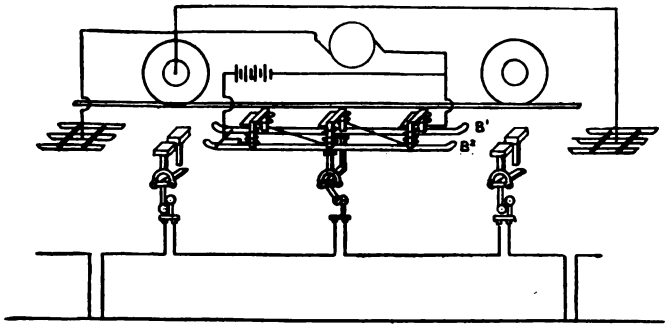

FIG. 2.—DOLTER.

—combine the two functions in the one apparatus, as follows:—

Underneath the car, running very close to the road surface, are two iron bars B^1 B^2, in length rather more than equal to the distance between two studs. These make contact with the latter, taking the place of the collecting skate. They also act as pole pieces to the series of electro magnets fixed along their upper surface, with the consequence practically all surface contact systems. Their function is to earth the rear road stud after the car has passed. If, through the failure of the switch, the contact is left alive, putting it to earth causes a short-circuit that blows a fuse in the branch cable to the stud. Figure 3 is a scale drawing of the latter.

The two contact blocks C C, upon which the skate bears, are of cast iron, separated by a small piece of non-magnetic manganese

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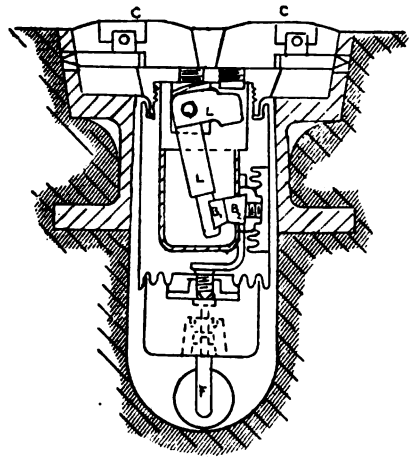

FIG. 3.—DOLTER.

steel. Into the bottom of these are screwed two iron studs, to the left-hand one of which is attached the pivot-bearing of a bell crank lever L L. This bearing is a large hole in which the pivot fits loosely; there is therefore no chance of friction or sticking. The upper arm of the lever is of iron, and forms a keeper for the two projecting screwed lugs. To the lower end is attached a carbon block B^1, and to the inner case is fixed a corresponding block B^2, connected directly to the branch feeder F, which is laid in a pipe at the bottom of the pit. The action has been described above, and in Fig. 3 the bell-crank lever is shown attracted upwards and the switch closed.

Attached to the lower part of the lever is a magnetic blow-out arrangement—not shown—that when excited by the series current is sufficient to destroy any arc that may be formed between the contacts. Under proper working conditions the opening is of course sparkless.

This system is fortunate in being one that has had a practical trial for nearly four years, and shown good results. It is installed on the Bois de Boulogne Railway Company's line, from which it has ousted the surface contact method of Vedovelli.

Other magnetic systems have been proposed; but with one or two notable exceptions, these have seldom got beyond a paper existence, or the experimental stage. They have mostly been based upon much the same principles as the Dolter, differing chiefly in the form of the armature that is acted upon by the car magnets, and in details of the switches: both important points, but needless to go into to obtain an appreciation of the magnetic system as a whole. We may therefore pass on to the second method, *viz.*—

ELECTRICAL SYSTEMS.

By the above designation is meant those systems which depend upon current transmitted to the stud for the operating of the switches, no actuating device being carried upon the car.

One of the earliest of these was Wynne's, illustrated in Fig. 4; it is also one of the first instances of the use of studs in the place of the sectional rail.

The studs were to be of iron, and placed equidistantly down the centre of the track. They were to be excited by a series coil, and in a chamber below each was to be fixed a hinged iron keeper, provided with a switch contact at its end. Below each of these, as shown, was a disc of iron connected through a thin spring arm to the feeder cable F. The path of the current was through this spring, the hinged arm and contacts, the winding, and the stud itself to the collecting skate Cs; but, when the latter touched a fresh stud in its forward movement, the current divided, part flowing as above, and part from the switch of S^2 along the connecting cable to the winding of S^1, which now became magnetised and picked up its own switch, so making connection with the cable.

In practice, such a system is impossible. The car can only move in one direction,

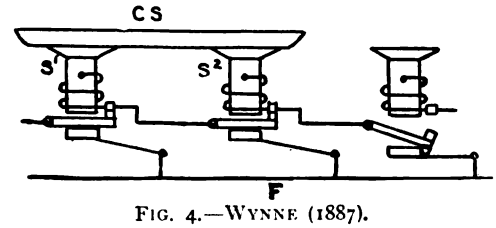

FIG. 4.—WYNNE (1887).

and if the skate made imperfect contact with the leading stud, sufficient current would not pass to actuate the switch. But the chief evil is that common to most electrically worked surface contact devices, *viz.*, the liability of surface leakage from the stud to earth being sufficient to energise the coil, and keep the switch closed after the car has passed.

Take S^2, which will shortly be left behind the car. It is obvious that if the road surface is sufficiently wet, current will pass from the stud to the rails; and, given the right conditions, this may easily be sufficient to keep the former alive.

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Many efforts were made by Wynne and others to overcome this difficulty, but nothing was ever done with the system in practice.

The Schuckert system, diagrammatically shown in Fig. 5, is a somewhat complicated one; and yet, from report, it seems to have given satisfaction at Munich, where it has been installed since 1899.

The appended connections are those of a single-track line, or one where cars are required to travel in both directions over the same metals. It is this that complicates the system; otherwise it is very simple.

Presuming the direction of running is from right to left, when the car-skate touches a stud, current is passed through its top magnet coil and the uppermost winding of the lower magnet of the *stud behind* it. This results in the attraction and closing of the front switch which is connected to the feeder F, and the pulling down and opening of the rear one. It will be seen that this is all that is necessary for moving in one direction only: switch CS^1 or CS^2, the top coils ending on its right-hand side, and the bottom on its left; and as the direction in which the car will run depends upon which of the two coils has its circuit closed, it is obvious that for a right to left direction the switch arm will be over to the right, and *vice-versâ*. Presuming that the track is used for traffic in both directions, a car moving from right to left will probably find all the control switches C S against it. These, however, it changes over automatically in the following manner. Up to stud 4 everything is as usual—the current passes round the closing coil of the stud the skate touches, and the opening coil of the one it has just left, through the control switch CS^1, which is over to the right; and so to earth.

But the moment it comes in contact with stud 5 the operation is different; the current passes through the closing coil of 5, the opening coil of 4, and then away to the right-hand magnet of the control switch of

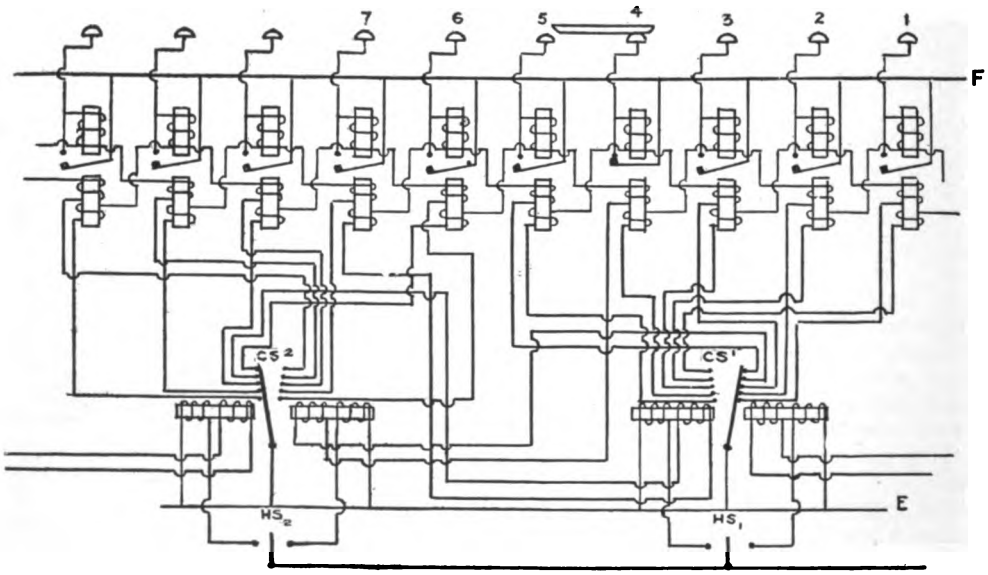

FIG. 5.--SCHUCKERT.

the leading stud is energised, and the trailing one switched off at practically the same moment. For the reverse direction of running, however, the bottom coil of the lower or opening magnet becomes necessary, and this, it will be noted, is connected in series with the closing coil of the magnet on the *other* side of the stud under consideration. Now, if either of the opening coils is traced out, it will be found to be connected to earth after passing through a common multiple the next section before returning to its own contact on CS^1. The arm of CS^2 is now pulled over to the right by the magnet, and so the car can proceed over all the studs controlled by this apparatus.

Magnets 4 and 7, it will be noticed, actuate the control switches in this manner; the former through the top coil, and the latter through the bottom. Should occasion arise to reverse the motion of the car while in the middle of a section, this is done by aid of

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the hand switches HS^1 and HS^2, which are connected to a shunt winding from the main; and according to the contact on which they are placed, so the control switch of the section will be pulled over to the right or left, thus reversing the opening connections of the stud magnets. These switches are placed at frequent intervals in the road. Each car carries a battery of accumulators to energise the magnet coils when starting, the amount required being half an ampere at 500 volts. The apparatus is centralised as much as possible; that is to say, several mechanisms are placed together in one large box, and connected to their separate studs by wires. This allows of easy inspection; and, although costly in cable, is necessary for the good working of the system.

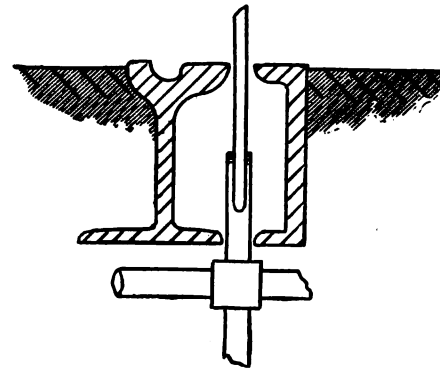

FIG. 6.—KINGSLAND.

The difficulties in connection with electrically operated methods, and their frequent failure, have done much to discredit surface contact traction as a system; and, judging from past experience, if it is ever to become more than a playground for inventors, it must, apparently, be carried out either upon magnetic or mechanical lines. The former have already been described: we now come to the alternative.

MECHANICAL SYSTEMS.

The want of success of early magnetic, and practically all electrically operated systems, led several inventors to try what could be done with mechanically worked switches; the idea being, that unless something broke, such switches could not fail to act. As simplicity is invariably a great feature, many of these methods have a very promising appearance; for instance, the Kingsland system brought out and experimentally tried at Wolverhampton some few years ago. Alongside one of the rails is built up a shallow conduit, of which the inner rail forms one side and a special rail the other; the flanges meet at the bottom, but at the top there is a $\frac{5}{8}$-inch clearance corresponding to that in an ordinary conduit system.

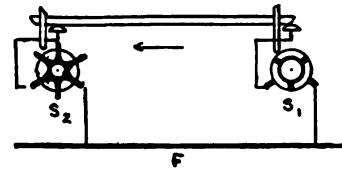

FIG. 7.—KINGSLAND.

This arrangement is broken every few yards on a level with the contact studs by a switch-box, consisting of a cast-iron case fitted internally with a special switch and a braking arrangement, both very simple and trustworthy in action.

From the side of the box nearest the rail projects the switch-spindle, on which is fixed a six-pointed star wheel, the arms of which project into the conduit, as shown in Fig. 6, the bottom flange of the rail being cut away at this point. On the car two ploughs are carried, one at the front and one at the rear, and these run continually in the conduit, striking the star wheels when they come to them, and shifting each round a sixth of a revolution.

The switch geared to the star wheel is of the commutator variety, having three segments all connected together internally, and an insulating substance between them. The action is shown in Fig. 7, the star wheel being removed on the right for the sake of clearness.

It will be obvious from the construction of the switch S_1, and the position of the brushes, that each sixth of a revolution alternately opens and closes the circuit. S_2 has just been moved round this amount by the leading plough, and the switch closed; S_1 at the same time having been opened by the rear plough and left in the position shown.

When the latter reaches S_2 it will push the star wheel round an arm, and so open the switch; the leading plough therefore always closes the switches, and the trailing one opens them. The braking arrangement fixed on the spindle is necessary in order to prevent the switch and wheel being carried round too far by their momentum. This is all there is in the system, which may justly claim to be one of the simplest.

Among other mechanical methods that have been devised, the most noteworthy is, perhaps, that of Allen and Peard, brought out in 1898; it is also simple and decidedly novel in its inception.

A box, shown somewhat diagramatically above, contains the road stud and is placed every few yards along the track. The lever L has, at the one end, a button B which

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projects into the groove of one of the rails, and at the other is attached to the moveable stud and kept in the down position by aid of a powerful spring S.

Underneath the spring, and insulated from everything but the stud, is what may be termed the switch arm; and opposite it, in connection with the feeder cable, is a bend of laminated copper which acts as the contact. As shown in the diagram, when the car wheel reaches the button in the rail, it presses it down and raises the other end of the lever up against the spring, lifting the moveable stud several inches above the level of the road, and making contact between it and the main. The collecting skate is a box-like arrangement, shown in section in Fig. 8, having two lips at the bottom for making contact with the under side of the stud, and holding it up in place after the wheel has left the button. When the skate leaves the contact it is pulled down again to its original position by the spring. This apparatus can scarcely fail to act, the motion being simple and positive. The action of the spring is strong enough to make the "break" a certainty, and, beyond the very remote chance of something becoming wedged under the stud while it is up, there appears to be no risk in this direction.

It is, of course, a very difficult matter to foretell the results that these or other systems would attain over a prolonged period of practical use. In most cases it is only possible to deduce conclusions, so few surface contact methods having experienced anything in the way of a fair trial.

In many places there is a demand for something less unsightly and primitive than the trolley wire; and there can be no question that the inventor, who succeeds in producing a surface contact system that in every way is beyond reproach, and, above all, can persuade the engineering world at large that he has done so, will reap a golden harvest that will well repay him for his pains.

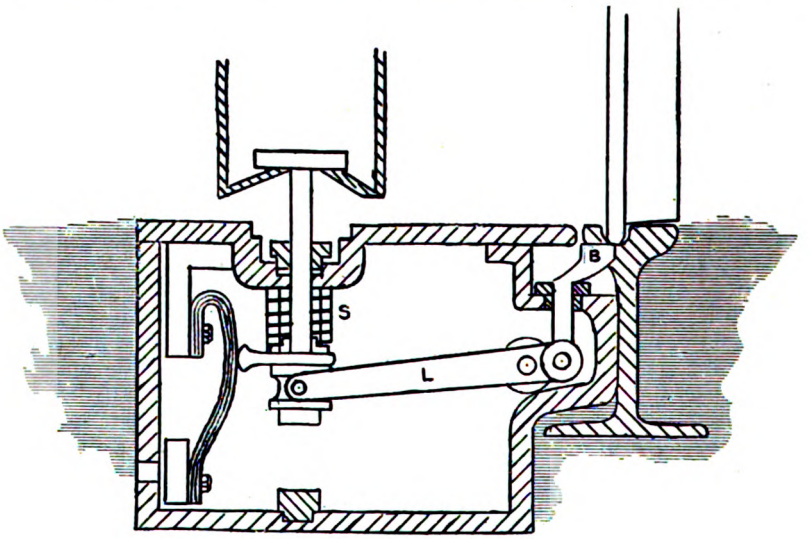

FIG. 8.—ALLEN-PEARD.

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RECENT INVENTIONS.

A New Process for Welding Aluminium.

THE Cowper-Coles process for welding aluminium requires no flux, and does not necessitate the hammering of the joint when in the semi-fluid state. The process is especially suitable for wire rods and tubes, and other drawn or rolled sections, and consists in placing the parts to be welded, after being faced off square, in a machine (Fig. 1) fitted with clamping screws, which are capable of moving horizontally on guides. The movement of the clamping screws is controlled by the levers D. The aluminium to be welded is heated by means of an ordinary benzine lamp: so soon as the rods have arrived at the necessary temperature, slight pressure is applied to the levers D, which causes the aluminium rods to unite, and a ring of metal is squeezed out, as shown in Fig. 2. This ring is largely composed of aluminium oxide, and acts as an insulating and supporting collar, the molten metal being retained within this. The weld is then instantaneously quenched by turning a handle attached to the screen, A, which allows water, under pressure, to be projected on to the joint from the reservoir, F. The same handle which turns the water on places the screen A in front of the heating flame; the water pressure is maintained by air supplied by the hand pump, E. The rod is finally removed from the machine, and the collar filed off, when it will be found that the joint is as strong as the rest of the metal. An oxygen-hydrogen flame or ordinary gas, with or without air, may be substituted for the benzine

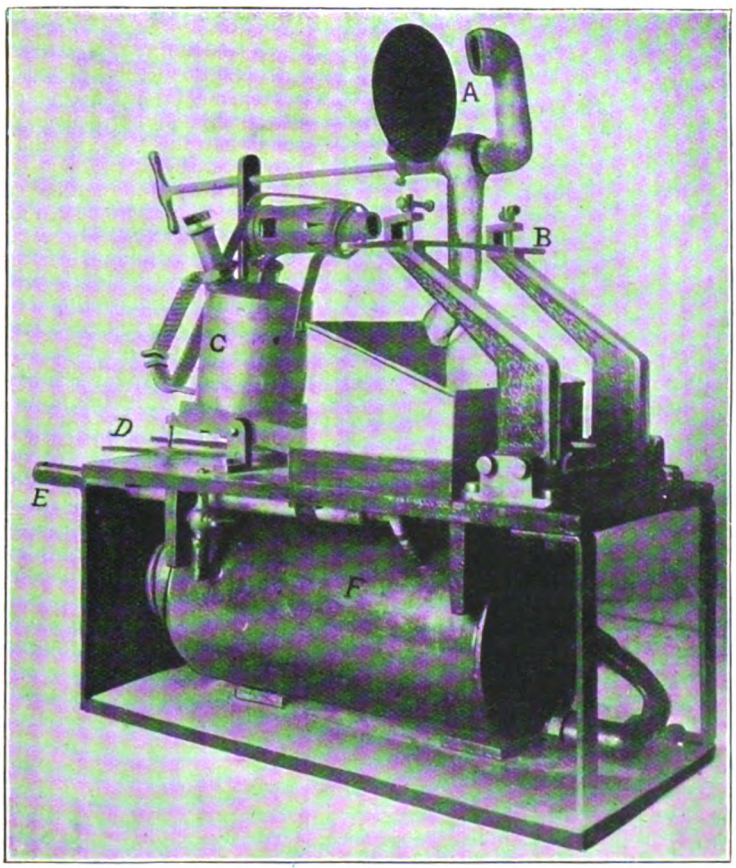

FIG. 1.—COWPER-COLES'S MACHINE FOR WELDING ALUMINIUM.

A, Screen; B, Aluminium Rods; C, Lamp; D, Levers for applying pressure; E, Pump; F, Water Reservoir.

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lamp. The process is a simple one, and can be worked by any unskilled workman. Fig. 3 clearly shows the molten aluminium supported by a pipe or case of aluminium oxide, the case having been pricked with a steel-point to allow some of the molten metal to flow out.

The following table gives the result

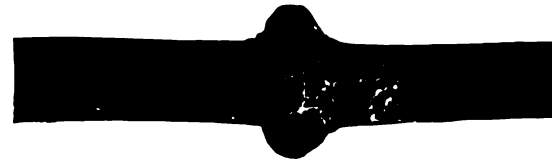

FIG. 2

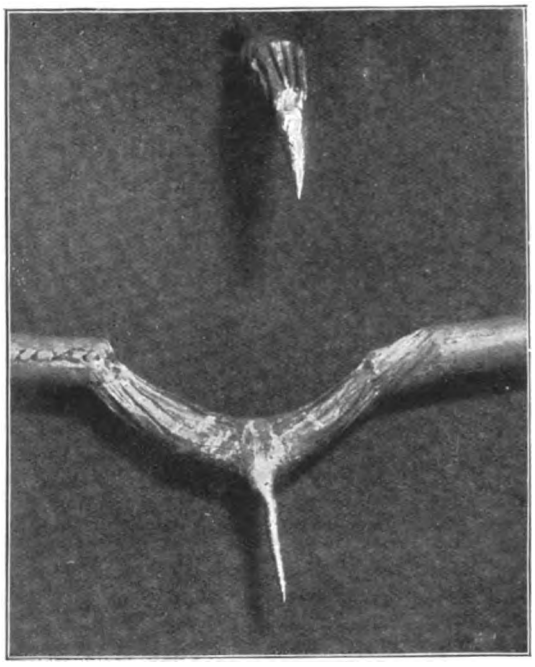

FIG. 3.

of tests for tensile strength on twelve consecutive welds (not picked specimens) made by the process just described. The fractures occurred at a considerable distance from the weld, showing that the metal was not deteriorated at the weld. In the twelve tests referred to, not one specimen broke through the welded portion.

PERMAN'S RADIOSCOPE.

This little instrument is a very convenient arrangement for showing the scintillations of radium on a blende screen. The effect is somewhat the same as in Crooke's Spinthariscope, but the radium is mixed with the zinc blende, the scintillations being spread over the whole surface of the latter. A very pleasing and striking appearance is produced, resembling a multitude of bright stars twinkling brilliantly in a dark sky. Moreover, in different instruments different effects are produced owing to differences in the arrangement of the radium salt. The effect is produced by the radiation from the radium known as the α-rays, which consist of minute particles of atomic size; these are projected forth with great velocity, and when they strike the blende screen cause cleavage of the minute crystals which they meet, the cleavage being accompanied by a flash of light or scintillation.

These or similar scintillations are being

TENSILE STRENGTH OF ALUMINIUM WELDS.

Dimensions.	Area.	Reduction of area at fracture.	Extension. On 4 in.	On Original Area.				Remarks.
				Elastic Limit (Yield Point).		Maximum stress.		
				Pounds.	Tons.	Pounds.	Tons.	
	Square inches.	Per cent.	Per cent.	Per square in.		Per square in.		
Diam. in.								
0·249	0·0487	7·4	8·0	11491	5·13	20249	9·04	Broke outside datum points.
0 248	0·0483	7·4	13·0	8803	3·93	22265	9·94	Ditto do.
0·254	0·0507	7·5	8·0	11043	4·93	19868	8·87	Ditto do.
0·252	0·0499	7·4	11·7	14358	6·41	16150	7·21	Ditto do.
0.252	0·0499	7·7	13·0	21996	9·82	21996	9·82	Ditto do.
0·250	0·0491	7·6	9·0	14134	6·31	19622	8·76	Ditto do.
0·250	0·0491	7·7	9·0	14134	6·31	14134	6·31	Ditte do.
0·254	0·0507	7·9	11·0	15030	6·71	24304	10·85	Ditto do.
0·251	0·0495	7·8	7·8	14940	6·67	20361	9·09	Ditto do.
0·253	0·0503	7·7	14·0	10236	4·57	19152	8·55	Ditto do.
0·250	0·0491	7·7	9·0	12320	5·50	20070	8·96	Ditto do.
0·247	0·0479	7·7	9·0	8422	3·76	18704	8·35	Ditto do.

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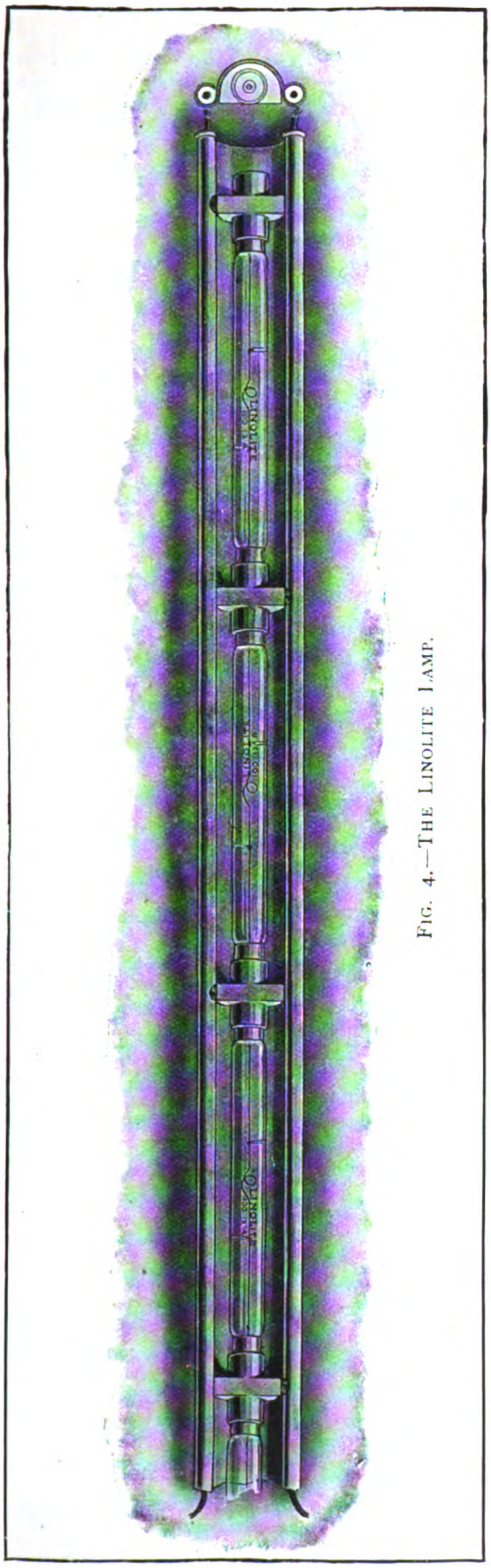

FIG. 4.—THE LINOLITE LAMP.

constantly produced spontaneously in hexagonal blende, and can be seen at any time, when the eye is sufficiently sensitive, by looking into a radioscope tube *without any radium;* but under the influence of the radium they are increased enormously in number and brightness.

The effect produced in this instrument is quite equal, if not superior, to that observed in the more expensive spinthariscope.

THE TWIN TUBE STEAM TRAP.

Fig. 6 (p. 400) shows a new form of expansion steam trap which is making many friends amongst engineers and steam users; and contrasts strongly with the "Float" type of trap, illustrated on page 167 of our February number.

The three-fold duty of an efficient steam trap may be defined as (*a*) the removal of all condensation from any given point; (*b*) to be accomplished without the slightest waste of

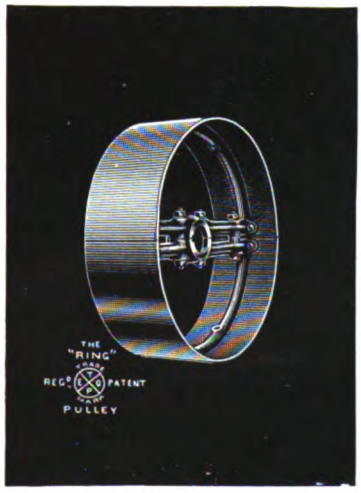

FIG. 5.—THE RING PULLEY.

steam; (*c*) and by such means as shall not require constant attention at the hands of the engineer in charge.

The first point calls for a good valve; the second, for an automatic, sensitive and powerful instrument to control that valve; while the third necessitates simplicity of construction.

The "Twin Tube" has a conical valve, with taper seat, which is controlled by the expansive and contractive movement of a Bourdon Tube—positive, unvarying, and of sufficient power to close the valve against the highest steam pressures employed in modern engineering.

The movement of the tube spring is not due to the expansion or contraction of metal, but to internal pressure, which is sensible to the slightest variation in temperature.

The trap is wide open when cold, and cannot close until steam reaches it. Thus air and water are allowed to escape from any pipes or apparatus to which the trap is attached, before the valve closes.

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For ordinary work, the outer tube or casing is made in cast iron (250 lbs. hyd., 150 lbs. steam test).

For high pressures, and marine service, the cast iron gives place to gun metal (500 lbs. hyd., 250 lbs. steam test).

The Patent "Ring" Pulley.

The Pulley illustrated in Fig. 5 (p. 399) has the boss, arms, and inner ring cast in one piece. It is then split in halves, the irregularity of the fracture making a close and interlocking joint when the halves are bolted together. The boss is then bored and the ring turned on its face to afford a true surface on to which the wrought iron rim is rivetted. It is then found that the combination of the ring with the two arms and the close joint gives great strength, combined with lightness, while the turned ring secures a true running pulley.

The "Linolite" Lamp.

The Linolite tubular lamps are exactly the same in principle as ordinary electric glow lamps; that is, the light is generated by an incandescent carbon filament in a glass tube from which the air has been exhausted. There are, however, one or two important points of difference. In the development of lighting, the tendency has been to produce a large quantity of intense light from a very limited area. In the Linolite lamps, the filaments are of the same length as those in ordinary glow lamps, but instead of being coiled up, as in the latter, they are quite straight, or have a small expansion loop at the centre. All parts of the filament are thus in the same position as regards the reflector, and the relative positions of these are such as give the greatest possible efficiency. Consequently the light is better distributed, and from two to four times the usual length of reflector is placed behind the same length of filament. This has been shown, by careful photometric measurements, to vastly increase the amount of light thrown forward throughout a very wide angle. It is claimed that the Linolite lamp enables a much greater percentage of the light generated to be efficiently used.

Fig. 6.—The Twin Tube Steam Trap.

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REVIEWS.

London County Council School of Photo-engraving and Lithography: Principal's Report for the Eighth Session, 1902–3. pp. 12 : plates XL. (London : Published by the Board at the School, 6, Bolt Court, Fleet Street, 1903.)

Reports of educational institutions can seldom be made so interesting as the one at present under consideration. The Bolt Court School was founded by the London County Council, to give instruction in the various processes of reproducing drawings and pictures ; and no one could wish for a more satisfactory test of the success achieved, than that afforded by the publication of reproductions carried through by the students at the School. Forty illustrations are reproduced, and each has considerable merit. The processes of greatest commercial importance are the relief processes, in which line blocks and half-tone blocks are used ; some excellent instances of these are given. Reproductions in colour are also included, the tricolour print, Plate XXXVII., being specially worthy of mention. The colour lithograph of an iris, Plate XXIV., is an excellent example of the results that can be obtained by nine printings. Several excellent lithographs are shown, among which may be mentioned that of a toreador, Plate XIX. Plate XIV., which is taken from Hobbema's picture of "The Avenue," Middleharnis, affords a good example of collotype printing. In a short introduction the various processes are briefly and lucidly described. It is stated that, in addition to teaching craftsmen the theory and practice of their trade, some effort is being made in the direction of elementary research. As a result, two novel processes have been developed by senior students. One of these, which is a process for producing illustrations of laces and other similar fabrics, gives most excellent results, as can be seen by reference to Plate VI. Altogether, the Principal and staff of the School may be heartily congratulated on the success which has obviously attended their efforts.

The Manufacture of Boots and Shoes : being a Modern Treatise on all the Processes of Making and Manufacturing Footgear. By F. Y. Golding, Principal of the City and Guilds of London Institute's Leather Trade School, pp. x + 294. (London : Chapman & Hall, 1902.) Price 7*s.* 6*d.* net.

In writing this interesting and instructive volume the author has aimed at producing a text-book useful to students attending technological classes, so that they should be enabled to supplement the knowledge gained in the class-room, and thus be able to cover a larger field than would otherwise be possible. These aims have been carried out with a thoroughness and lucidity which should ensure instant success. The book has not been prepared for cram purposes ; on the contrary, the student is led, step by step, beginning with an anatomical consideration of the human foot, through every development of boot and shoe manufacture. The second chapter, on "Characteristics, Contours, and Types of Feet, etc.," is particularly good. The third chapter is occupied with foot-measurements ; British, American, French, and German methods are described. Subsequent chapters are devoted to sole shapes and last-making : upper pattern making and grading : clicking, or cutting upper leathers ; and upper fitting, and machining or closing. Students of shoemaking can be confidently recommended to procure this book, of which the study should place them in a position to grasp the essential difficulties of their craft, together with the most recent methods of overcoming these.

Logarithms for Beginners. By Charles N. Pickworth, Wh.Sc. pp. viii + 48. (London : Whittaker & Co., 1904.) Price 1*s.*

It is now clearly recognized that a competent knowledge of the use of logarithms is necessary to nearly every type of student ; and Mr. Pickworth's book is well calculated to convey this knowledge in a simple form. Starting with a consideration of the law of indices, the meaning of a logarithm is deduced, while the properties of logarithms are determined step by step in a lucid manner. Four tables of logarithms and antilogarithms (four figure) are given at the end of the book. It is a pity that tables of trigonometrical ratios are not also included, as these, treated in the same simple style, would undoubtedly add to the value of this already valuable little book.

Friction and its Reduction. By G. U. Wheeler, Wh.Sc., A.M.I.Mech.E. pp. viii. + 171. (London: Whittaker & Co., 1903.) Price 3*s.* net.

The efficiency of any machine depends, to a greater or less extent, on the character of the lubrication supplied to its bearings. This being so, it is satisfactory to obtain a concise *résumé* of the results of experiments on friction and lubrication, previously to be found only by searching through the proceedings of the various scientific and engineering societies ; together with practical details, such as the price of oils, balls, and ball bearings. The subject is simply but adequately treated, and is illustrated by line diagrams of some of the most important systems of lubrication. A useful index is appended.

Practical Chemistry. Part II. By W. French, M.A., F.I.C., and **J. H. Boardman,** M.A. pp. xiv. + 126. (London : Methuen & Co., 1904.) Price 1*s.* 6*d.*

This volume forms a continuation of the scheme adopted by Mr. French in Part I. of *Practical Chemistry*. The first 26 pages are devoted to a study of the physical properties of gases, including elasticity, density, diffusion, and solubility ; each property being illustrated by suitable experiments of an elementary character.

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Subsequently the laws of chemical combination, equivalent weights of elements, the atomic theory, and chemical equations are dealt with. A good foundation having thus been laid, the student is introduced to the study of some of the most important chemical compounds. Sixty-nine practical questions are appended, together with several tables and a short index.

Introduction to Metallurgical Chemistry for Technical Students. By J. H. Stansbie, B.Sc., F.I.C. pp. VIII.+ 200. (Bristol: John Wright & Co., 1903).

Before entering on the serious study of metallurgy a certain amount of preparation is necessary, and this book has been written in order to provide students with a means of obtaining this preparatory training. It has been written for those who are practically interested in the common metals, but possess no further knowledge than can be obtained in the ordinary workshop or foundry. The greater portion of each chapter is occupied by a description of the chemical properties of the common metals; and, in the development of chemical principles, these metals are chiefly considered. The great importance of carbon, when alloyed with iron, is fully recognized, and its properties are carefully dealt with. Combustion and reduction are also carefully considered. The book is mainly practical in character, and a large number of illustrative experiments are included in the text. Students commencing the study of metallurgy cannot do better than procure and study this work.

Graphs and Imaginaries. By J. G. Hamilton, B.A., and **F. Kettle,** B.A. pp. 41. (London: Edward Arnold, 1904.) Price 1*s.* 6*d.*

The graphic solution of quadratic equations, so far as real roots are concerned, is well recognized and appreciated. In the above volume the authors extend this method, so that the imaginary roots of a quadratic equation can be obtained as easily and accurately as real roots. The parabola enables us to find the real roots of any quadratic equation; thus there seems to be some warrant for the conclusion that an intimately related curve would perform similar functions for imaginary roots. Experiment and investigation confirm this inference, and the authors have worked out in detail a few typical cases chosen from elementary and analytical geometry. The graphs and diagrams are excellently reproduced.

Gas and Oil Engine Management: A Practical Guide for Users and Attendants. By M. Powis Bale, M.I. Mech. E., A.M.I.C.E. pp. viii. + 110. (London: Crosby, Lockwood & Son, 1903.)

Those entrusted with the charge of gas and oil engines will doubtless derive benefit from this volume, in which the practical difficulties they are likely to meet with are concisely and simply dealt with. In a sense, the treatment consists in a diagnosis of the various ills which gas and oil engines are heir to, with simple instructions for their remedy. Some useful tables and an index are added.

Geometry for Technical Students. By E. H Sprague, A.M.I.C.E. pp. viii. + 60. (London: Crosby Lockwood & Son, 1904.) Price 1*s.* net.

It is coming to be generally recognized that Euclidian geometry presents unnecessary difficulties to students, and therefore needs modification. By starting with the theory of parallel lines, Continental mathematicians have shown that a large number of the less important propositions can be omitted, the results obtained being equally trustworthy. This system has been used by Mr. Sprague, who also introduces the idea of ratio at an early point in the treatment. A good feature is the consideration of terms and definitions as they are required. Students commencing the study of geometry may advantageously follow the course prescribed in this volume.

Organs and Tuning: A Practical Handbook for Organists. By Thomas Elliston, Organist of St. Gregory's, Sudbury. pp. xii.+ 368. (London: Weekes & Co., 1898, with addenda). Price 3*s.* 6*d.* net.

This volume contains an interesting and instructive description of the church organ, in its entirety and in detail. Some most valuable practical memoranda are added on pp. 73–84. A number of working specifications are given, together with a useful vocabulary of stops and technical terms. Thirty-six pages of addenda have just been added by the author.

Saw Mill Work and Practice: A Book for Owners, Overseers, and Operators of Woodworking Machinery. By W. J. Blackmuir. pp. vi. + 158. (London: William Rider & Son, Ltd.) Price 3*s.* 6*d.*

In writing this book the author has aimed at describing wood-working machinery from the standpoint of the man who has to use such machinery, or at least, is responsible for its proper treatment and use. It has evidently been written by one who has gained his knowledge from long and intimate acquaintance with the class of machinery discussed. No diagrams of machinery are given, the only illustrations reproduced being of a very simple character. Nevertheless, the object aimed at by the author has been achieved, and the persons for whom the book has been written will find much valuable information of the most practical character possible. The printing is, however, very bad.

The Story of the Atlantic Cable. By Charles Bright, F.R.S.E., A.M.Inst.C.E., M.I.E.E. pp. 220. (London: George Newnes, Ltd., 1903). Price 1*s.*

In spite of the brilliant possibilities which wireless telegraphy has held out, there appears to be no immediate prospect of dispensing with cables in long-distance telegraphy. In telling the story of the Atlantic cable, Mr. Bright carries us back to past times when long-distance telegraphy, even with the aid of cables, was by many considered to be chimerical. The difficulties encountered, and the success at last achieved, are described in a simple and readable manner.

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ANSWERS TO QUERIES.

Students wishing for the solution of problems, or assistance in their scientific or technical studies, are invited to consult the Technical Editor by letter. Queries should be accompanied by the name and address of the sender, together with a nom de plume *for publication. Queries obtained from text-books or examination papers should be accompanied by particulars of the sources from which they are derived. Queries should reach us before the 10th of the month, to be answered in the next month's issue. Each inquirer is restricted to one query per month.*

GALVANOMETER.—A small galvanometer needle, swinging freely in the earth's magnetic field, makes 3 complete oscillations per second. The strength of the field in which the needle swings is diminished by the control magnet of the galvanometer, until the time of one complete oscillation is 2 seconds. Find by how much the "zero position" of the needle will be altered by a change in the magnetic declination of one minute of arc. If the needle is attached to a mirror, and a spot of light is reflected on to a millimetre scale at 50 cms. distance from the mirror, by how many millimetre divisions will the zero position of the spot of light be changed under the above conditions ?

The time of oscillation of a magnetic needle, controlled only by the magnetic field in which the needle swings, varies inversely as the square root of the controlling field ; in other words, the controlling field varies inversely as the square of the time required for a complete oscillation of the magnetic needle. Thus, if H is the strength of the earth's field in the above problem, while F is the resultant field due to the difference between the earth's field and that of the control magnet, then—

$$\frac{F}{H} = \frac{(1)^2}{(2)^2} = \frac{1}{36}.$$

Thus the field due to the control magnet must act in direct opposition to the earth's field H ; the magnitude of the former being $\frac{35}{36}$ H.

Let OH, Fig. 1, represent the initial value of the earth's field, while OF represents the constant value of the field due to the control

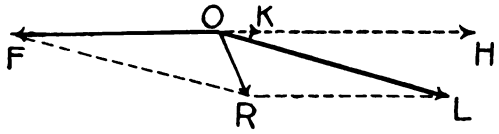

FIG. 1 (GALVANOMETER).

magnet. Then OK represents the resultant field, its value being $\frac{H}{36}$. The N pole of the needle will point along the direction OK. If the earth's field now changes its direction to OL, its numerical magnitude remaining constant, then the needle will point along the resultant OR of the two fields OF and OL. To find OR, complete the parallelogram FOLR, and draw the diagonal OR. KOR represents the angle through which the needle is deflected. Then, by trigonometry—

$$(OR)^2 = (OL)^2 + (LR)^2 - 2\,OL.LR \cos OLR,$$

and since RL is parallel to FO, and therefore to OH, the angle OLR must be equal to LOH, or 1′. Also, since OL = OH = H, while LR = OF = $\frac{35}{36}$ H, we have

$$(OR)^2 = H^2 + \left(\frac{35\,H}{36}\right)^2 - \frac{2.H.35\,H}{36} \cos 1'.$$

Now cos 1′ is so nearly equal to 1 that the difference may be neglected.

$$\text{Then } (OR)^2 = H^2 + \left(\frac{35\,H}{36}\right)^2 - \frac{2.H.35\,H}{36}$$

$$= \left(H - \frac{35\,H}{36}\right)^2 = \left(\frac{H}{36}\right)^2.$$

$$\therefore OR = \frac{H}{36}.$$

$$\text{Then, } \frac{\sin LOR}{\sin RLO} = \frac{LR}{OR} = \frac{\frac{35\,H}{36}}{\frac{H}{36}} = 35.$$

$$\therefore \sin LOR = 35 \sin RLO.$$

Since the angles RLO and LOR are both small, the sines are directly proportional to the angles. Thus—

$$LOR = 35 \times RLO = 35 \times 1'.$$

$$\therefore KOR = KOL + LOR = 1' + 35' = 36'.$$

Thus the needle will be deflected through 36 minutes of arc.

The normal to the needle will also be deflected through 36′, and therefore, by a well-known law of optics, the beam of light reflected from the mirror will be deflected through twice this angle, or 72′.

Let x be the number of millimetre divisions through which the spot of light on the scale moves ; then since the scale is 50 cms., or 500 mm. distant from the mirror, and the displacement of the spot of light subtends an angle of 72′ at the mirror, we have—

$$\frac{x}{500} = \text{circular measure of } 72' = 0{\cdot}0209 \text{ radians.}$$

$$\therefore x = 500 \times 0{\cdot}0209 = 10{\cdot}45 \text{ mm.}$$

ELECTRON.—Find the number of watts in one horse-power, being given that 1 ft. = 30·48 cms., 1 lb. = 453·6 grams, g = 981 cms. / sec².—*London University, B. Sc. Pass* 1902.

A *horse power* corresponds to the performance of 33,000 ft.-lbs. of work per minute, or 550 ft.-lbs. per second.

A *watt* corresponds to the performance of 10^7 ergs of work per second.

1 lb. = 453·6 grams, and on each gram gravity exerts a force of 981 dynes. Thus on 1 lb. gravity exerts a force of 453·6 × 981 dynes.

If 1 lb. is raised through 1 ft. or 30·48 cms.,

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the work performed will be equal to

$$453{\cdot}6 \times 981 \times 30{\cdot}48 \text{ ergs.}$$

Therefore 550 ft. lbs. per second is equivalent to $453{\cdot}6 \times 981 \times 30{\cdot}48 \times 550 = 746{\cdot}1 \times 10^7$ ergs. per second $= 746{\cdot}1$ watts.

STATICS.—The ends of a massless flexible string are fastened to the extremities of a heavy rod, and the string is then hung over a frictionless pulley. In what position will the rod come to rest?

It can be proved that the rod will be in a state of stable equilibrium only when it hangs vertically. For let AB, Fig. 1, represent the rod hanging in any inclined position, the string APB passing over a small frictionless pulley at P. To be in equilibrium, the middle point C of the rod must be vertically beneath P. From P draw PR vertically downwards, to represent the weight of the rod on a convenient scale. Then PR represents the vertical pull on the pulley P, and this must be equal to the resultant of the tensions of the strings PA and PB. From R draw R*a* parallel to BP, and R*b* parallel to AP. Then P*a* and P*b* must represent the respective tensions of the strings PA and PB.

Now, since the pulley is frictionless, equilibrium cannot be maintained when the tensions along PA and PB are unequal; in the case represented in Fig. 1, where the tension along PA exceeds that along PB, the string will run over the pulley in the sense BPA, and equilibrium will be attained only when the rod occupies a vertical position, in which case the tensions along both strings will be equal. Thus, if one end of the rod is initially ever so little lower than the other end, the lower end of the rod will commence to descend, and the motion set up will only cease when the rod has come into a vertical position. When the rod is horizontal it will be in unstable equilibrium, since the tensions of the two strings are then equal, but a small displacement will lower one or other of the ends of the rod, in which case it will not return to the horizontal position, but move as previously described.

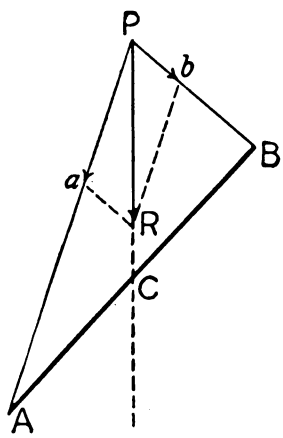

FIG. 1 (STATICS).

PIANOFORTE.—In the pianoforte the vibration of the strings is transmitted to the sounding board by means of a wooden bridge. Since a node must be formed at the bridge, in what way is the motion transmitted?

A node is generally defined as a stationary point on a string; but in practice a node is a point where the motion is of a very small order of magnitude. When, in its motion, the string rises above its equilibrium position, there will be less downward pressure on the bridge then when the string was horizontal. Then the bridge, which was compressed when the string was horizontal, expands upwards when the string moves upwards. For similar reasons the bridge suffers an extra compression when the string sinks below its equilibrium position. Consequently the bridge is subjected to alternate expansions and compressions, and these are transmitted downwards to the sounding board, which is caused to vibrate and thus produces sound waves in the surrounding air.

EXMOUTH.—I am anxious to make a model of an existing triple expansion engine, to illustrate the effects of the inertia of the moving parts, and to show the beneficial effects that arise from balancing. This I propose to do by means of a skeleton model (Fig. 1, p. 405) driven by means of a flexible coupling to a motor or lathe, the model being supported on four spiral springs of known strength.

Am I right in assuming that the weights of the piston line, etc., of the real engine and model vary directly as the cubes of their linear dimensions?

If I determine the weight which will compress the springs to the extent observed experimentally when the model is working, shall I obtain the actual pressures on the seating of the real engine if I multiply this weight by the cube of the ratio which the linear dimensions of the engine bear to those of the model?

If the crank shaft and piston rods, etc., of the model are made from the same materials as in the real engine, their forms being similar, so that the model is a reproduction of the engine on a smaller scale, then the out-of-balance weights of the two will vary directly as the cubes of their linear dimensions. The pressures, etc., on the seating of the engine will not, however, vary in this proportion. Suppose that an unbalanced rotating mass m is at a distance r from the axis of rotation; then the centrifugal force produced when the angular velocity of rotation is equal to ω, will be equal to $m\ r\ \omega^2$. Thus since m varies as the cube, and r as the first power of the linear dimensions; if the speeds of the engine and model are equal, the rotating weights which are not *dynamically* balanced will produce a pressure varying as the fourth power of the linear dimensions. This reasoning applies to the crank shaft; this may be *statically balanced*, but it is easily seen that great pressures may be produced during rotation; for the portions of the crank shaft which are farthest from the axis of rotation may produce forces at a given instant, which tend to urge one end of the shaft down and the other end up, and *vice versâ*. This want of dynamical balance of rotating parts may produce very serious vibrations in certain circumstances. The effect of this could be determined by disconnecting the piston rods in the model, and running at the same speed as the engine.

The unbalanced piston rods also produce pressures. It is necessary to remember that the force at any instant called into play is proportional to the *rate of change of momentum* of the moving parts. Let us suppose that the model is run at the same speed as the real

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engine. Then if we assume the motion of the piston rods to be of the simple harmonic type, the *rate of change of velocity* varies as the amplitude, *i.e.*, as the length of stroke. Then since the unbalanced masses vary as the cube, and the stroke as the first power of the linear dimensions, the pressures produced will vary as the fourth power of the linear dimension. If the speeds differ, then the pressure produced will vary as the squares of the speeds.

Thus if the model is $\frac{1}{4}$ of the size of the real engine, both being run at the same speed; and the springs are compressed $\frac{1}{10}$ inch by a weight of 5 lbs., and during running the springs are compressed $\frac{8}{10}$ of an inch, then the pressure produced on the seating of the real engine will be

$$5 \times 8 \times 4^4 = 10{,}240 \text{ lbs.}$$

Some further precautions are required in order to obtain trustworthy results. First of all, the springs should be so stiff that the period of vibration of the framework is much smaller than the period of revolution of the shaft. If this condition is not complied with, the frame will be unable to follow rapid vibrations. If the period of vibration of the framework is equal to that of the rotating shaft, very small forces may set up vibrations of considerable magnitude—vibrations out of all proportion to the applied forces.

E.G.N.—The conclusion arrived at in the answer to Dobb's question (p. 205 of February "Technics") is that the man and weight both ascend at the same rate. If we admit that the force transmitted by the rope to the weight is equal to the force raising the man, then two equal forces act on the pulley and produce equal and opposite turning moments, with the result the pulley would be in equilibrium. In this case I cannot see why the pulley rotates.

The pulley will remain at rest, or *in motion with a constant velocity*, so long as it is acted upon by equal and opposite turning moments. When the man starts to climb, the upward force acting on him must exceed the force pulling him downwards; the greater the rate at which his upward velocity increases, the greater must be the force raising him. This force is transmitted by the cord. If we take the inertia of the pulleys into account, then the tension of the rope must set the pulley in rotation and also raise the counterbalancing weight; in this case the velocity acquired by the weight will be somewhat less than that of the man. Disregarding the inertia of the pulley, and the weight of the rope, the man and weight must rise at exactly the same rate, because equal forces act on both, and both have equal masses. If the man climbs by jerks, each jerk acts equally on himself and on the weight, and both rise similarly.

SPECTRA.—What is the best type of spectroscope for observing the absorption spectra of fluids—prism or diffraction grating? Is there any atlas or work published containing fair-sized coloured spectra of the metals and metalloids?

The spectrum obtained by the use of a grating is less bright than one formed by a prism, so that a prism spectroscope is preferable for observing the absorption spectra of fluids. A direct vision spectroscope might be used with advantage. Dr. Watts has published a work on the line spectra of the elements, and this contains, we believe, large coloured maps of the spectra of a number of metals.

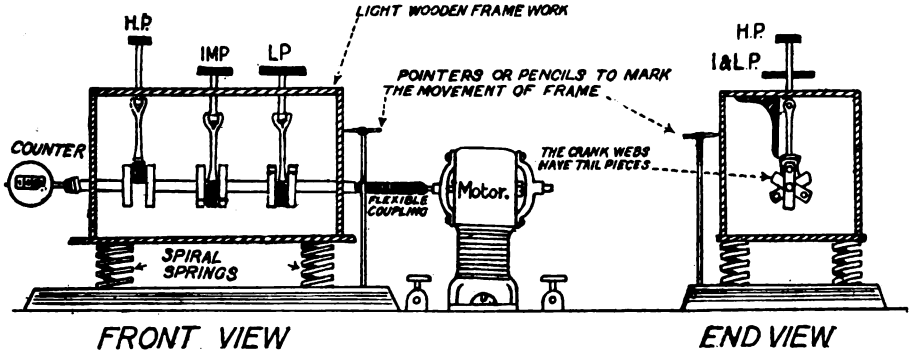

FIG. 1 (EXMOUTH).

DYNAMICS.—How can I calculate the time taken to destroy the momentum of a weight attached to one end of a string of which the other end is fixed, when the weight is allowed to fall from a given height?

To solve this problem, we must know the elasticity of the string. Let us suppose, when the string is stretched by a weight, that the addition of m grams produces an additional elongation of d cms. Then the weight, in gravitation units, which will produce unit elongation is equal to $m/d = M_1$ grams per cm. (say).

Let us suppose that the weight actually attached to the string is equal to M grams, and that it is initially raised H cms. above the position which it would occupy if the string were just straightened out without being stretched. Also, let h be the distance below this latter point to which the weight actually descends. Then the work done by gravity on the falling

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weight is equal to M (H + h) gram-cms. Stretching the string through h cms. generates a tension equal to $M_1 h$ gravitation units. Since the tension varies from zero (when the string is just straightened without being stretched) to $M_1 h$ (when the momentum of the weight is just destroyed, and an elongation of h cms. has been produced) the *average* tension during stretching must be equal to $(M_1 h)/2$ gravitation units. Thus the work done in stretching the string =

$$\frac{M_1 h}{2} \times h = \frac{M_1 h^2}{2} \text{ gram. cms.}$$

Then by the law of conservation of energy

$$M(H + h) = \frac{M_1 h^2}{2}$$

$$h^2 - 2\frac{M}{M_1} h = 2\frac{M}{M_1} H$$

$$\therefore h = \frac{M}{M_1} \pm \sqrt{\left(\frac{M}{M_1}\right)^2 + 2\frac{M}{M_1} H} \quad . \quad . \quad (1)$$

To determine whether the + or − sign applies to this problem, notice that if H = 0, and the weight is released at unit distance above its position of equilibrium; in these circumstances, if H = 0, and M = M_1 the weight will descend unit distance *below* its position of equilibrium, and oscillate vertically about the latter point. For these conditions to be complied with, we must retain the + sign. The maximum tension of the string is found by substituting the value of h given in (1), in $M_1 h$.

If we suppose that gravity ceases to act on the mass at the instant when it has just straightened the string, then the mass will subsequently be acted upon by a retarding force proportional to its distance below this point. This is the condition for the performance of a simple harmonic motion. At a quarter period after passing through the above point the mass will momentarily come to rest; and since the complete period of the vibration would be

$$2\pi\sqrt{\frac{M}{M_1 g}},$$

the actual time required to destroy the momentum of the weight will be

$$\frac{\pi}{2}\sqrt{\frac{M}{M_1 g}}$$

When H is fairly large, this will give a close approximation to the time required to destroy the momentum of the falling body.

TRACTO.—A 7-lb. brick is attached to one end of a mile of 16-gauge steel wire. Could an average man, by pulling at the other end of the wire, drag the brick along any surface such as smooth asphalt or ice? And about what force would be required?

If the surface were concentric with the earth, and were perfectly smooth, so that there was no friction between it and the brick and wire, then the smallest applied force would *move* the brick. In these circumstances the force, in absolute units, would be equal to the mass of the wire and brick, multiplied by the acceleration or rate of increase of velocity. By diminishing the acceleration the necessary force could be made as small as we please.

The force necessary to pull the brick along an actual surface concentric with the earth would be equal to the mass of brick and wire multiplied by the co-efficient of friction between these and the surface. If, instead of a brick, we had a 7-lb. block of steel, and the surface on which it and the wire lay were also of steel, then we might assume an approximate co-efficient of friction equal to 0·1. A No. 16 S.W.G. wire has a diameter of 0·064 inch. A mile of steel wire of this size would weigh something like 60 lbs. Then $\frac{1}{10} \times 67 = 6{\cdot}7$ lbs. Thus a man could easily pull a 7-lb. block of steel along a steel surface by the aid of a steel wire of No. 16 S.W.G.

R. F. L.—What is the meaning of a "short circuit"?

The term "short circuit" is applied to a conducting path of negligible resistance connecting two points in an electric circuit

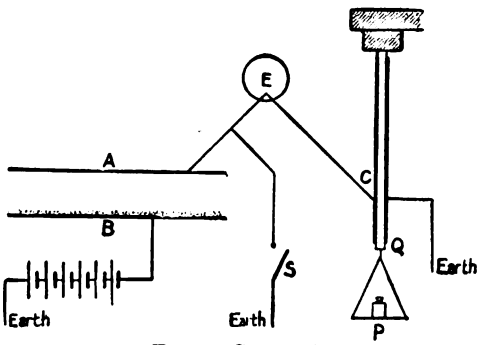

FIG. 1 (CURIOUS).

initially at different potentials. Thus, if we short-circuit a galvanometer, we connect its terminals by a wire or other conductor of negligible resistance. If we short-circuit a dynamo, we join its terminals by a conductor of small resistance.

CURIOUS.—Describe the construction and action of a quartz balance, and show how it is used in measuring radio-activity.

The quartz balance used by Mme. Curie for measuring the radio-activity of radium consists of a plate of quartz Q cut perpendicular to the axis (Fig. 1), with layers of tinfoil on its opposite faces. When the quartz is strained by placing weights in the scale pan P, the two opposite faces become oppositely electrified, and the two sheets of tinfoil are brought to different potentials.

The radio-active substance is placed on a horizontal plate B, which is connected to the negative terminal of a powerful battery, the positive terminal being earthed. Above B is another horizontal plate, A, connected to an electrometer E; when the switch S is closed the plate A is earthed. The radium converts the air in the

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space between A and B into a conductor of electricity, with the result that, if S is unclosed, the potential of A falls and causes a deflection of the electrometer E. The electrometer is also connected to one armature of the quartz condenser Q. By placing weights in the scale-pan P, the positive electricity disengaged on the armature C can be made to exactly compensate the negative electricity communicated to A, so that the electrometer remains undeflected. This arrangement was used by Mme. Curie in comparing the radio-activities of the various substances contained in pitchblende, and it was by this means that she was able to isolate radium. For the method of obtaining the atomic weight of radium, see answer to "Radio," February "Technics" (p. 304).

PHYSICS.—Let there be any surface density σ in a field, and any volume density ρ. Denote the distance of a point P from any element of surface ds by r, and the distance from any element of volume dv by r_1. The potential at P is given by the expression

$$\int\int \frac{\sigma}{r}\, ds + \int\int\int \frac{\rho}{r_1}\, dv.$$

—Mathematical Theory of Electricity and Magnetism, by W. T. A. Emtage, M.A.

The potential at a point d cms. from a charge q, is equal to q/d. If there are a number of charges q_1, q_2, q_3 . . . . at distances d_1, d_2, d_3, ... from the point, then the potential there is equal to

$$\frac{q_1}{d_1} + \frac{q_2}{d_2} + \frac{q_3}{d_3} + \quad . \quad . \quad . \quad . \quad .$$

Now on unit area of the surface there is a charge σ. Consequently there is a charge $\sigma\, ds$ on the surface element ds, and the potential of this at a distance r is equal to $(\sigma\, ds)/r$. The potential due to the whole of the charged surface is found by adding together the potentials due to the various elements of surface, or by integrating the expression $(\sigma\, ds)/r$ over the whole of the surface.

If ρ is the volume density (charge per unit volume) then the charge in a small element of volume dv would be $\rho\, dv$. The potential at a point r_1 cms. from this element of volume will be equal to $(\rho\, dv)/r_1$, and the total potential at the point is found by integrating this expression throughout the volume. In cartesian co-ordinates $dv = dx\, dy\, dz$; in this case the second integral must be integrated, first with regard to z, then with regard to y, and finally with regard to x.

W. J.—A cast-iron column, 5 ins. internal and 7 ins. external diameter, has a bracket attached to it, and a weight of twenty tons is carried by the bracket at a distance of 12 ins. from the axis of the column. Estimate the maximum and minimum stresses induced in the column and show, by means of a sketch, how the stress varies across the section.
—City and Guilds Mechanical Engineering, 1903.

In this column there are bending stresses induced by the excentricity of the loading in addition to purely compressive stresses. The direct uniformly distributed compressive stress

$$= \frac{\text{Load}}{\text{sectional area}} = \frac{20 \text{ tons}}{18{\cdot}8 \text{ sq. ins.}}$$
$$= 1{\cdot}06 \text{ tons per sq. inch.}$$

The bending stresses due to the excentricity of loading must now be found.

Let Z = section modulus

$$= \frac{\text{Moment of inertia}}{\frac{1}{2} \text{ external diameter.}}$$
$$= 24{\cdot}9 \text{ ins.}^3.$$

Let f = maximum tensile or compressive stress due to bending.

The bending moment = 20 tons × 12 inches.
= 240 ton-inches.

The moment of resistance = Zf

Since bending moment = moment of resistance,

$$240 \text{ ton-inches} = Z \times f$$
$$\therefore 240 \text{ ton-inches} = 24{\cdot}9 \text{ ins.}^3 \times f$$
$$\therefore \frac{240 \text{ ton-ins.}}{24{\cdot}9 \text{ ins.}^3} = 9{\cdot}6 \frac{\text{tons}}{\text{ins.}^2} = f.$$

In the figure let X X be the base line.

Let A B represent the external diameter of the column.

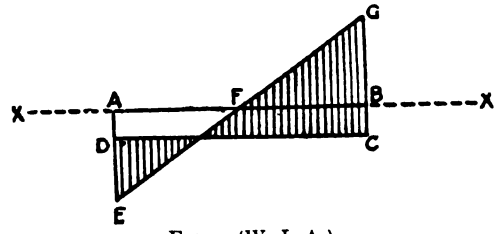

FIG. 1 (W. J. A.).

Then the rectangle A B C D represents the stress intensity diagram due to pure compression.

The figure F A E F G B F represents the bending stress intensity diagram.

The shaded portions represent the combination of the two diagrams.

The maximum compressive stress
= (9·6 + 1·06) tons per sq. inch.

The maximum tensile stress
= (9·6 − 1·06) tons per sq. inch.

The loading is obviously excessive.

O.T.D.—If three equal particles are projected vertically upwards from a point with equal speeds V, at times separated by equal intervals t; and if, when a rising and falling particle meet, they combine to form one particle; prove that the three particles become united at a time $\left(\frac{V}{g} + \frac{7}{6}t\right)$ after the projection of the first, t being less than $\frac{6V}{5g}$.
—Cambridge Mathematical Scholarship.

Let T denote the time that has elapsed from the projection of the first particle, x, y and z the distances of the three particles from the point of projection at the time T, then

$$x = VT - \tfrac{1}{2}gT^2,$$
$$y = V(T-t) - \tfrac{1}{2}g(T-t)^2,$$
$$z = V(T-2t) - \tfrac{1}{2}g(T-2t)^2;$$

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x and y are equal at some time T_1 given by

$$V T_1 - \tfrac{1}{2} g T_1^2 = V(T_1 - t) - \tfrac{1}{2} g (T_1 - t)^2;$$
$$\therefore T_1 = \frac{V}{g} + \frac{t}{2}.$$

From the well-known equation $V^2 - v^2 = 2gs$ we see that particles projected from the same point with equal speeds have the same v^2 at the same level. Hence the rising and falling particles having equal masses come to rest on collision. (This follows at once from the Law of Impact : Total Momentum before = Total Momentum after Impact.) At impact, the distance of the double particle from the point of projection is given by

$$x_1 = V\left(\frac{V}{g} + \frac{t}{2}\right) - \tfrac{1}{2} g \left(\frac{V}{g} + \frac{t}{2}\right)^2$$
$$= \frac{g}{2}\left(\frac{V^2}{g^2} - \frac{t^2}{4}\right).$$

The distance of the double particle at any time T is given by

$$x = x_1 - \tfrac{1}{2} g \left(T - \frac{V}{g} - \frac{t}{2}\right)^2$$

and when this is equal to z at some time T_2 we have

$$\frac{g}{2}\left(\frac{V^2}{g^2} - \frac{t^2}{4}\right) - \tfrac{1}{2} g \left(T_2 - \frac{V}{g} - \frac{t}{2}\right)^2$$
$$= V\left(T_2 - 2t\right) - \tfrac{1}{2} g \left(T_2 - 2t\right)^2$$
$$\therefore \frac{g}{2}\left(\frac{V^2}{g^2} - \frac{t^2}{4}\right) = V\left(T_2 - 2t\right)$$
$$+ \tfrac{1}{2} g \left(2T_2 - \frac{V}{g} - \frac{5}{2} t\right)\left(\frac{3}{2t} - \frac{V}{g}\right).$$

Hence

$$\frac{3}{2} g T_2 t = \frac{g}{2}\left(\frac{V^2}{g^2} - \frac{t^2}{4}\right) + 2Vt$$
$$+ \frac{g}{2}\left(\frac{5}{2t} + \frac{V}{g}\right)\left(\frac{3}{2} t - \frac{V}{g}\right)$$
$$= -\frac{g t^2}{8} + \frac{15}{8} g t^2 + \frac{3}{2} V t;$$
$$\therefore \frac{3}{2} g T_2 = \frac{7}{4} g t + \frac{3}{2} V;$$
$$\therefore T_2 = \frac{7}{6t} + \frac{V}{g}.$$

For the first collision to be possible we must have $t < \frac{2V}{g}$, for the second to be possible we must have $2t < \frac{7}{6} t + \frac{V}{g}$

$$\text{or } \frac{5}{6} t < \frac{V}{g} \text{ or } t < \frac{6V}{5g}.$$

INTEGRAL.—Integrate

$$\int \frac{dx}{x\sqrt{a^n + x^n}}$$

—*Edward's Integral Calculus for Beginners, No.* 19.

Let $a^n + x^n = \frac{1}{y^2}$; hence $x^n = \frac{1 - a^n y^2}{y^2}$.

Then $n x^{n-1} dx = -\frac{2}{y^3} dy$,

and dividing by x^n we get

$$n \frac{dx}{x} = -\frac{2}{y^3} \cdot \frac{y^2}{1 - a^n y^2} dy$$

and $$\frac{n\, dx}{x\sqrt{a^n + x^n}} = -\frac{2y}{y(1 - a^n y^2)} dy$$
$$= -\frac{2\, dy}{1 - a^n y^2}.$$

Hence $$\int \frac{dx}{x\sqrt{a^n + x^n}} = -\frac{2}{n} \int \frac{dy}{1 - a^n y^2}$$
$$= -\frac{2}{n a^{\frac{n}{2}}} \int \frac{d\left(a^{\frac{n}{2}} y\right)}{1 - a^n y^2}$$
$$= -\frac{1}{n a^{\frac{n}{2}}} \log \frac{1 + a^{\frac{n}{2}} y}{1 - a^{\frac{n}{2}} y}$$
$$= \frac{1}{n a^{\frac{n}{2}}} \log \frac{\sqrt{a^n + x^n} - a^{\frac{n}{2}}}{\sqrt{a^n + x^n} + a^{\frac{n}{2}}}$$

Another method would be to substitute $x^n = a^n \tan^2 \theta$, when the integral reduces at once to $\int \frac{d\theta}{\sin \theta}$, a known form.

X.Y.Z.—Integrate

$$\int \frac{x^2\, dx}{(x \sin x + \cos x)^2}$$

—*Edward's Integral Calculus for Beginners, No.* 20, *page* 85.

Let I be the value of the given integral.

Now $$\frac{d}{dx} \frac{1}{x \sin x + \cos x} = -\frac{x \cos x}{(x \sin x + \cos x)^2}.$$

Integrating by parts, we obtain

$$= -\int \frac{x}{\cos x} d\left(\frac{1}{x \sin x + \cos x}\right)$$
$$= -\frac{x}{\cos x (x \sin x + \cos x)}$$
$$+ \int \frac{1}{x \sin x + \cos x} \cdot \frac{\cos x + x \sin x}{\cos^2 x} dx$$
$$= \frac{x}{\cos x (x \sin x + \cos x)} + \int \sec^2 x\, dx$$

$$\int \frac{x^2\, dx}{(x \sin x + \cos x)^2}$$
$$= -\frac{x}{\cos x (x \sin x + \cos x)} + \tan x.$$

JET.—To measure the power in a three-phase system by the two wattmeter method, the algebraic sum of the two wattmeter readings gives the total power in the circuit. When the power factor of the system is below 0·5, the algebraic sum of the wattmeter readings is their difference. Why is this? Also show by means of a diagram the effect of the variation of the power factor.

It may be proved, both experimentally and mathematically, that the measurement of power in a polyphase system of q phases is given by the algebraical sum of the readings of $(q - 1)$ wattmeters ; so that in a three-phase system two wattmeters are sufficient for the determination of the power, whatever may be the power-factor

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or whether the system be balanced or not. Thus, with the arrangement shown in Fig. 4, in which W_1 and W_2 are the two wattmeters, the power absorbed in the circuit is

$$W = W_1 + W_2 = I_2 E_{12} + I_3 E_{13}$$

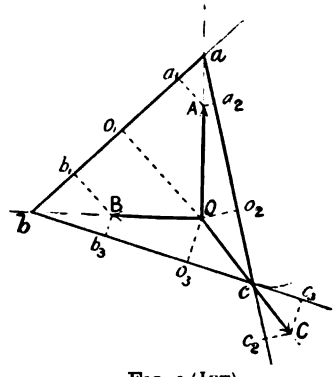

FIG. 1 (JET).

where E_{12} and E_{13} denote the pressures between the line wires 1 and 2 and 1 and 3 respectively, and I_2 and I_3 are the currents traversing the series coils of the wattmeters. When there are distinct phase-relationships between the currents and the pressures on account of reactance,

$$W = I_2 E_{12} \cos \theta_1 + I_3 E_{13} \cos \theta_2$$

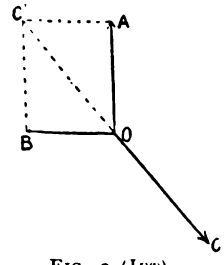

FIG. 2 (JET).

where θ_1 and θ_2 denote the angles of lag between the currents and pressure; and it follows that in the case of inductive circuits attention must be paid to the relative signs of cos θ_1 and cos θ_2. In a balanced system $\theta_1 = \phi_1 - 30°$ and $\theta_2 = \phi_2 + 30°$, if ϕ_1 and ϕ_2 are the angles of lag of the circuit currents and

$$W = I_2 E_{12} \cos (\phi_1 - 30°) + I_3 E_{13} \cos (\phi_2 + 30°).$$

Now, when $\phi_2 = 60°$, the power factor—*i.e.*, cos 60°—is 0·5 and cos $(\phi_2 + 30°)$ = 0, and the second wattmeter gives no reading and indicates no power, whilst if ϕ_2 is greater than 60°, the power factor (cos ϕ_2) is less than 0·5 and cos $(\phi_2 + 30°)$ is negative, in which case the arithmetical difference between the two wattmeter readings gives the power absorbed in the circuit.

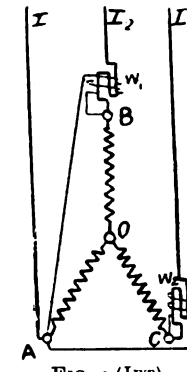

FIG. 4 (JET).

The following graphical treatment will probably make these facts clear. Let OA, OB and O C (Fig. 2) denote the magnitudes and phase-relationships of a three-phase system, and let the voltages be denoted by the delta diagram *a b c* (Fig. 1). To make use of this method the delta diagram should be constructed on a separate piece of tracing paper; then if the power factor be unity, it will be found that upon super-imposing the delta diagram of the voltages upon the Y diagram of the currents, the corners of the delta diagram fall on the legs of the Y, as in Fig. 1. By projecting the currents upon the sides of the delta diagram it will be found that

$$a_1 o_1 \times a b + c_3 o_3 \times c b = W$$
$$a_2 o_2 \times a c + b_3 o_3 \times b c = W$$
$$b_1 o_1 \times b a + c_2 o_2 \times c a = W$$

If the power factor be cos ϕ then the delta of the voltages must be rotated through an angle equal to the angle of lag, ϕ, of the system (Fig. 3), and by projecting the currents as before it will be found that a_1, the projection of A, is on the side of o_1 remote from the corner *a* of the delta, and $o_1 a_1 = - a_1 o_1$ therefore

$$- a_1 o_1 \times a b + c_3 o_3 \times c b = W$$
$$a_2 o_2 \times a c + b_3 o_3 \times b c = W$$
$$b_1 o_1 \times b a + c_2 o_2 \times c a = W$$

In the figure $c_2 o_2$ is very small, and if ϕ were slightly greater $c_2 o_2$ would be zero, and thus correspond to the case where the power factor = cos 60° = 0·5. Upon further increasing ϕ, $c_2 o_2$ would become negative.

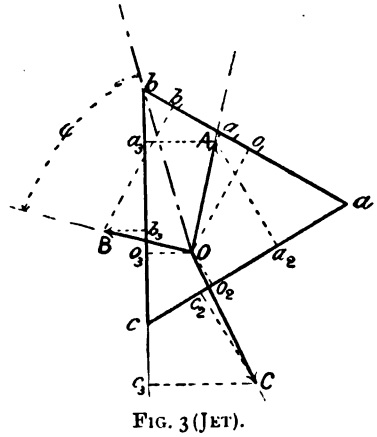

FIG. 3 (JET).

MAGNETIC FIELD.—Iron filings are sprinkled over a sheet of paper on which a magnet lies; prove that all those filings which dip towards the same point on the line of the magnet lie on a circle (neglecting their mutual actions).

Suppose N S to be the magnet, Q the given point, and P a point on the given locus at which the direction of the magnetic field is P Q.

Let N P = r_1, S P = r_2, P Q = R, and the angles as shown in the figure.

The repulsive force along N P = $u = \frac{k}{r_1^2}$.

The attractive force along S P = $v = \frac{k}{r_2^2}$.

Hence $\frac{u}{v} = \frac{r_2^2}{r_1^2}$.

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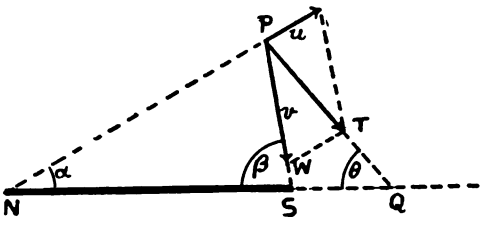

FIG. 1 (MAGNETIC FIELD).

But from figure, $\frac{u}{v} = \frac{\sin \text{S P Q}}{\sin \text{P T W}} = \frac{\sin(\beta - \theta)}{\sin(\alpha + \theta)}$.

Let N Q $= a$, and S Q $= b$.

Then $\frac{\text{R}}{a} = \frac{\sin \alpha}{\sin(\alpha + \theta)}$

and $\frac{\text{R}}{b} = \frac{\sin \beta}{\sin(\beta - \theta)}$.

Hence $\frac{u}{v} = \frac{b \sin \beta}{a \sin \alpha} = \frac{b}{a}\frac{r_1}{r_2} = \frac{r_2^2}{r_1^2}$;

$\therefore \frac{b}{a} = \frac{r_2^3}{r_1^3}$

and $\frac{r_2^2}{r_1^2} = \left(\frac{b}{a}\right)^{\frac{3}{2}}$.

Also from the figure

$$r_2^2 = \text{R}^2 + b^2 - 2\,b\,\text{R}\cos\theta,$$
$$r_1^2 = \text{R}^2 + a^2 - 2\,a\,\text{R}\cos\theta.$$

Hence

$$\frac{\text{R}^2 + b^2 - 2\,b\,\text{R}\cos\theta}{\text{R}^2 + a^2 - 2\,a\,\text{R}\cos\theta} = \left(\frac{b}{a}\right)^{\frac{3}{2}} = c \text{ (say)}.$$

This is the polar equation to a circle with Q as origin.

The Cartesian equation with Q as origin is

$$(x^2 + y^2)(1 - c) - 2x(b - ac) + b^2 - a^2c = 0,$$

from which the centre of the circle can easily be found.

INTERMEDIATE.—A train, 100 tons gross, fitted with continuous brakes, is to be run on a level line between stations one-third of a mile apart, at an average speed of twelve miles per hour, including two-thirds of a minute stop at each station. Prove that the weight on the driving wheels must exceed 22½ tons, with an adhesion of one-sixth: neglecting road resistance and delay in application of brakes. Prove that the line could be worked principally by gravity if the road is curved downwards between the stations to a radius of about 11,740 feet, implying a dip of 33 feet between the stations, a gradient at the stations of 1 in 13, and a maximum running velocity of 31 miles per hour.—*London University, Inter. B.Sc. Engineering*, 1903.

The statement that the train is fitted with continuous brakes implies that a brake is fitted to each wheel of the train. The tangential force on the rim of the wheel produces an equal force on the axle, retarding the train. Let this force be equal to P_2 lbs. When the brakes are on, the retarding force, P_2, will be equal to 1/6 of the weight of the train.

Let P_1 lbs. be the direct pull of the engine. If W_1 is the weight on the driving wheel, then P_1 will be equal to $W_1/6$.

Let M be the mass of a body, acted upon for t_1 seconds by a force f. Then the velocity v generated in this time is given by the equation

$$\text{M}\,v = f\,t_1.$$

Let M be the mass of the train, t_1 the time from starting the engine to stopping it, and v the velocity of the train at the end of this time. The pulling force f is equal to $P_1 g$ poundals. Then

$$\text{M}v = P_1 g\,t_1;\ \therefore t_1 = \frac{\text{M}\,v}{P_1 g}. \quad . \quad . \quad . \quad (1)$$

The instant the engine ceases to act, let the brakes be applied, bringing the train to rest in t_2 seconds. Then, since the resisting force is equal to $P_2 g$ poundals, and a momentum M v is destroyed in t_2 seconds, we have

$$\text{M}\,v = P_2 g\,t_2;\ \therefore t_2 = \frac{\text{M}\,v}{P_2 g}. \quad . \quad . \quad (2)$$

Let the time from starting to stopping, $(t_1 + t_2)$, be equal to t.

Then, adding (1) and (2), and transforming, we obtain

$$\frac{\text{M}\,v}{g} = \frac{P_1 P_2}{P_1 + P_2}.t \quad . \quad . \quad . \quad (3)$$

In the time t_1, in which the engine increases the velocity of the train, from zero to v, let the train move over a distance s_1. Then, since frictional forces are neglected, the kinetic energy of the train is equal to the work performed

$$\tfrac{1}{2}\,\text{M}\,v^2 = P_1 g\,s_1;\ \therefore s_1 = \frac{\text{M}\,v^2}{2\,P_1 g} \quad . \quad . \quad (4)$$

Similarly, if s_1 is the space in which the train is brought to rest by the resisting pull $P_2 g$, we have

$$\tfrac{1}{2}\,\text{M}\,v^2 = P_2 g s_2;\ \therefore s_2 = \frac{\text{M}\,v_2}{2\,P_2 g} \quad . \quad (5)$$

Adding (4) and (5), substituting $s_1 + s_2 = s$, and transforming, we obtain

$$\frac{\text{M}\,v^2}{2g} = \frac{P_1 P_2}{P_1 + P_2}s. \quad . \quad . \quad . \quad (6)$$

Dividing (6) by (3), we obtain

$$\frac{v}{2} = \frac{s}{t}.$$

This result might also be obtained from the consideration that during the first t_1 seconds, the velocity of the train increases uniformly from o to v, so that during this interval the average velocity is equal to $v/2$. During the second interval t_2, the velocity decreases uniformly from v to o, so that in this interval the average velocity is also equal to $v/2$. Consequently the average velocity from start to stop (*i.e.*, s/t) must be equal to $v/2$.

The booked time between stations ⅓ mile apart, the average speed being twelve miles per hour, is 100 secs. Deducting 40 seconds for the stop, the actual running time = 60 secs.

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$$v = \frac{2s}{t} = \frac{3520}{60} = \frac{176}{3} \text{ ft. per sec.}$$

From (3)

$$\frac{M}{P_1} + \frac{M}{P_2} = \frac{gt}{v} \quad . \quad . \quad . \quad . \quad (7)$$

Since each of the quantities on the left of this equation is a ratio, we may obviously measure M_1, P_1, and P_2, in tons instead of in pounds, without incurring any error.

Then in (7), $M = 100$ tons,
$P_2 = 100/6$ tons,
$g = 32$,
$t = 60$,
$v = \frac{176}{3}$;

$$\therefore \frac{M}{P_1} = \frac{32 \times 60 \times 3}{176} - 6;$$

$$\therefore P_1 = \frac{1100}{294}.$$

The weight W_1 on the driving wheel must be equal to 6 P_1;

$\therefore W_1 = 22{\cdot}45$ tons, or $22{\cdot}5$ tons (roughly).

Let us now suppose that the line is to be worked by gravity. Let R be the constant radius of curvature of the road in a vertical plane, the starting and stopping stations being on a level. Then (in the absence of friction) the time t required for a train to travel from one station to the other will be equal to the time required for a pendulum of length R to complete one-half of a complete swing.

$$t = \pi \sqrt{\frac{R}{g}}$$

$$R = \frac{t^2 g}{\pi^2}$$

Since $t = 60$ secs., we obtain, if $g = 32{\cdot}17$

$$R = 11{,}740 \text{ ft.}$$

Let δ be the dip between the stations. Then

$$(2R - \delta)\delta = \left(\frac{s}{2}\right)^2.$$

Neglecting δ^2 in comparison with $2R\delta$, we obtain

$$\delta = \frac{s^2}{8R} = \frac{(1{,}760)^2}{8 \times 11{,}740}$$
$$= 33 \text{ ft. (nearly).}$$

At the stations the road is inclined downwards at an angle of which the circular measure is practically equal to

$$\frac{s}{2} \div R = \frac{s}{2R} = \frac{830}{11{,}740} = \frac{1}{14} \text{ nearly.}$$

Thus the gradient is practically 1 in 14.

In a simple harmonic motion, the maximum velocity is obtained by multiplying the amplitude by $2\pi/T$ where T is the time of a complete vibration. In the present case, the amplitude $= s/2 = 830$ ft., while $T = 2 \times 60$; $\therefore$ maximum velocity =

$$\frac{2\pi}{120} \times 830 = 43{\cdot}4 \text{ ft. per sec.}$$

The maximum velocity V can also be determined from the formula

$$V^2 = 2g\delta = 64 \times 33$$
$$V = 8\sqrt{33} = 45{\cdot}9 \text{ ft. per sec.}$$
$$= 31{\cdot}33 \text{ miles per hour.}$$

TRANSFORMER.—What are the measurements, number and thickness of the windings for a transformer, changing an alternating current of one ampere at 120 volts into 6 amperes at 20 volts?

It is not possible to design a transformer to convert one ampere at 120 volts into 6 amperes at 20 volts, since this would give an efficiency of conversion of 100 per cent., which is impossible. As no frequency is mentioned, the following data have been calculated for a periodicity of 100 per second. The type of transformer is shown in Fig. 1A, and the laminated core is built up, about the coils, with 60 pairs of L-shaped strips of good transformer iron ·015 inch thick, separated from one another with thin tissue paper, so that the section of the core is about one inch square. The dimensions of the separate strips are given in Fig. 1B. The primary winding consists of 1,000 turns of No. 20 gauge insulated wire, and the secondary consists of 166 turns of No. 13 gauge insulated wire, the former being placed under the latter, and the whole set of windings are divided equally into two portions, so that 500 turns of the primary and 83 turns of the secondary winding are on each of the two limbs of the transformer. When the coils have been wound they should be well insulated from one another, and the whole well wrapped with several layers of tape. The laminated sheets of iron forming the core are bolted together, so that the complete transformer has the appearance shown in Fig. 1A.

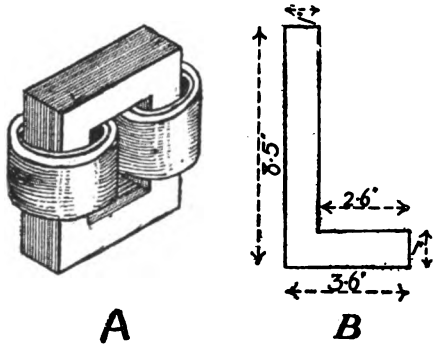

FIG. 1 (TRANSFORMER).

STEEL-FACING.—I am very anxious to find out both the plant and process of what is known to the fine-art printing trade as steel-surfacing. If you could enlighten me on the subject, or tell me where I could learn it, I should feel greatly obliged.

An account of this process can be found in Gore's Metallurgy (Longmans Green & Co.). Your best course would be to attend the classes at the Northampton Institute, where the subject of steel-facing is gone into thoroughly. The process is simple, but requires demonstration.

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PLATO.—Ash saplings after five years' growth are worth 1s. 3d. and increase in value 1s. 3d. each year afterwards. For their growth each tree requires twice as many square yards as the number of years it is intended to grow before cutting. Find the greatest annual income which can be obtained per acre, allowing 20% for expenses.— *Brooke-Smith's Arithmetic, p.* 392.

The value of each tree when ready for cutting = 1s. 3d. + (1s. 3d.) × (number of years of growth *minus* 5) = $\frac{5}{4}$ shillings × (number of years *minus* 4).

Hence, total income from plantation in shillings = $\frac{5}{4}$ × number of trees cut per annum × (number of years *minus* 4). Since expenses are 20%, $\frac{4}{5}$ of this is the total net income, and, therefore, total net income

$= \frac{4}{5} \times \frac{5}{4} \times$ no. of trees × (no. of years *minus* 4).

Hence, net income per acre × no. of acres

= no. of trees × (no. of years *minus* 4).

Each tree requires twice as many square yards as the years it has grown, or

$$2 \times \frac{\text{no. of years of growth}}{4840} \text{ acres}$$

$$= \frac{\text{No. of years}}{2420} \text{ acres.}$$

Hence the number of acres of trees cut down each year

$$= \frac{\text{No. of years} \times \text{no. of trees}}{2420}.$$

But when the whole plantation has been cut over, those planted after the first cutting must be of the proper age, and we therefore obtain the total acreage by multiplying the number of acres cut per year by the number of years of growth. Thus: Total acreage

$$= \frac{\text{No. of years} \times \text{no. of trees} \times \text{no. of years}}{2420}.$$

But net income per acre, in shillings,

$$= \frac{\text{No. of trees} \times (\text{no. of years } \textit{minus } 4)}{\text{No. of acres.}}$$

Hence, income per acre

$$= \frac{\text{No. of years } \textit{minus } 4}{(\text{No. of years})^2} \times 2420 \text{ (shillings)}$$

When the number of years is

6, then	$\frac{\text{No. of years } \textit{minus } 4}{(\text{No. of years})^2}$	$= 1\frac{1}{8}$
7 ,,	,,	$= \frac{3}{49}$
8 ,,	,,	$= \frac{1}{16}$
9 ,,	,,	$= \frac{5}{81}$
10 ,,	,,	$= \frac{3}{50}$

The greatest return will therefore be produced if the trees are cut down when 8 years old, and in that case—

The net income per acre $= \frac{2420}{16}$ shillings,

$= £7$ 11s. 3d.

TECHNICS CORRESPONDENCE.

To the Editor of TECHNICS.

SIR,—From the interesting article by Mr. James Swinburne on "Incandescent Electric Lamps," in your February issue, I gather that the material for the filament of the lamp which is now "in almost universal use" is cellulose, which has been acted upon or "dissolved" by a solution of chloride of zinc.

My own work in connection with the filament for incandescent lamps is not referred to; but I am under the impression that the above material was invented by myself, after a long series of experiments carried out at the School of Electrical Engineering in Hanover Square. In 1881 I took out a patent (No. 3890 in that year), in which I claimed as my invention: "In the manufacture of carbon for electric lighting, the use of a concentrated solution of zinc chloride, substantially as and for the purpose or purposes hereinbefore set forth and described."

In my process, as carried out in the manufacture of what, I believe, were undoubtedly the first incandescent lamps with filaments produced from cellulose gelatinised by means of zinc chloride, the material was not "squirted." Filaments having the same resistance for a given length were obtained by treating Swedish filtering paper with a cold solution of zinc chloride, having a specific gravity of 1·876 or thereabouts; and, after suitably washing and pressing the gelatinised cellulose, and drying it at 212° Fahr., strips were cut from the sheet (resembling semi-transparent horn) which strips were drawn through a die. I am inclined to think that greater uniformity of filament can be obtained by these means than by squirting the gelatinised material.

Some of the experimental lamps manufactured, under my supervision, by the pupils of the school above mentioned, were tested by Mr. W. M. Mordey, M.I.E.C., at the works of the Brush Company. The intention was to increase the current gradually until the filaments were broken down; but the experiments, if I remember rightly, came to an untimely end by the effect of the "extra current" produced on breaking the circuit, which happened to be one of high inductance.

Sir William Crookes at one time constructed lamps with filaments made from cellulose which had been treated with a solution of cupric ammonide. I remember giving him a sample of material to compare with his own.

I am, Sir, Yours truly,

DESMOND G. FITZ-GERALD.

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"TECHNICS" COMPETITIONS.

A GOLD MEDAL and £200

To be awarded Annually to the "Technics" Prizeman.

£50 IN PRIZES OFFERED IN THIS ISSUE.

PARTICULARS of 39 competitions have been given in the January, February, and March numbers of "Technics."

The present number contains particulars of 12 competitions, for which money prizes amounting, in the aggregate, to £50 will be awarded.

At the end of the year, a prize of £200 in cash, and a Gold Medal, will be awarded to the competitor who has shown the most care, thought, and accuracy in the year's competitions.

£50 IN PRIZES.

General Rules.

Competitors are requested to note the following rules :—

All writing must be on foolscap paper. Only one side to be written upon, and a reasonable margin left.

Competitors should see that their drawings are sent either rolled or flat—flat preferred. They must not be creased. They must also be executed in black ink.

N.B.—All drawings, and each page of MS., must bear a *nom-de-plume*, and must be accompanied by a closed envelope containing the name and address of the Competitor. The outside of the envelope must bear the Competitor's *nom-de-plume* only.

The Editors reserve the right to publish, without further payment, contributions that gain prizes. Should any article or drawing that has not gained a prize be published in the magazine, payment will be made at the usual rate.

Should the best answer in any competition be deemed of insufficient merit, the Editors reserve the right to withhold the prize.

All competitions must be addressed to the Competition Department, "Technics," 3 to 7, Southampton Street, Strand, W.C., and must reach these offices not later than May 10th. Results will be published as soon as possible.

In each case the work will be submitted to an expert competent to declare which is the best practical suggestion, design, or article.

GENERAL COMPETITIONS.

1. The best and second-best Homework Book, or set of books, in each of the three following subjects :—

(*a*) *Physics*, or any of its branches, *viz.* :— Properties of Matter, Heat, Light, Sound, or Magnetism and Electricity.

(*b*) *Engineering* (Mechanical or Civil), or any branch of these subjects, such as Steam, Structural Design, Surveying, etc.

(*c*) Electrical Engineering.

First prize for each subject, £3. Second prize for each subject, £2.

Each book submitted must be signed by the teacher or professor, as a guarantee of good faith. Stamps for return of books should be sent.

Homework prizes in other subjects will be announced in the May number of "Technics."

2. Explain the hydro-dynamical law, "Where the velocity is greatest, the pressure is least." Give instances of striking phenomena and mechanical appliances which depend on the truth of this law. Prize £3.

3. State what you know of mercerisation. Prize £3.

4. Give details of the design of an alternating current transformer of 5 K.W. capacity, the voltage of supply being 1,000 volts, and the ratio of tranformation, 10 : 1. Prize £3.

5. Houses built on the London clay are liable to crack, owing to the swelling of the clay when moist, and its shrinkage on drying. Describe how the design of a house should be modified in such circumstances. Prize £3.

6. The best essay on "The Duties of a Central Station Electrical Engineer." Prize £3.

7. The best answers to each of the four sets of questions coming under the head of Special Competitions, on page 414. Prize £5 for each set.

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SPECIAL COMPETITIONS.

QUESTIONS BEARING ON ARTICLES IN THIS NUMBER.

I.

QUESTIONS ON DYNAMOS.

(1) In the light of all the considerations as yet touched upon in the articles, and of any other reasons which occur to you, discuss the advantages and disadvantages of employing very few slots per pole in continuous-current machines. How is the question affected by the rated voltage of the machine, and by the consideration of its being a very small motor or a very large generator?

(2) Discuss the field for the use of mica in dynamo-electric machinery.

(3) What is the armature slot space-factor of the 400 K.W. design described in the preceding articles?

(4) Describe briefly the progress made in the last few years in the use of insulating materials in dynamo manufacture. In what directions do you look for further progress? Consult leading text-books on the design of dynamo-electric machinery.

II.

QUESTIONS ON THEORY OF STRUCTURAL DESIGN.

(1) Submit dimensioned drawings on separate sheets, and to a scale of 3 in. = 1 ft., for the following :—

(*a*) A cast iron bedplate or bearing plate resting on brickwork.

(*b*) A York stone template or bearing plate resting on brickwork.

The bearing plates must safely support a 24 in. × 7½ in. × 100 lb. per foot rolled steel joist, carrying a distributed load of 20 tons across a clear span of 40 ft.

In each case suitable provision must be made against the joist taking its bearing on the upper inner edge of the bearings.

(2) Give a sketch and description of the model or diagram which, to your mind, most clearly illustrates the internal compressive and tensile stresses in a bent beam. The source of the sketch should be stated, where possible.

(3) Describe three instances of shearing force, and give illustrative sketches. Examples of shear in beams or cantilevers are not to be quoted.

(4) Attempt a partial or complete solution of the following problem :—A cantilever, 6 ft. long, projects 5 ft. from the face of a wall, and is let into the wall for a distance of 12 in. There is a uniformly-distributed load of 4 tons resting along the projecting portion.

To a horizontal scale of half natural size and a vertical scale of 1 in. = 10 ton-inches, plot the bending moments in ton-inches at intervals of an inch for the 12 in. of cantilever within the wall, and for the projecting 12 in. nearest to the wall, *i.e.*, for a distance of 2 ft. from the fixed extremity. Each ordinate should be figured. Assume other conditions which you consider probable and reasonable. State consecutively and concisely what assumptions you make.

III.

QUESTIONS ON STEEL.

(1) Describe and discuss the effects of cold-rolling on steel bars.

(2) Draw a stress-strain curve for steel, as obtained with the most sensitive apparatus. Discuss the form of this curve, and distinguish between the *true* and the *apparent* yield points.

(3) Describe and discuss the effects of heat treatment on steels of different characters.

(4) Describe and discuss the use of various liquids to quench steel for hardening purposes. What is the effect of adding small quantities of salt or sulphuric acid to water, and how do these differ from the effects produced by adding a small quantity of soap?

IV.

QUESTIONS ON PETROL MOTORS AND MOTOR CARS.

(1) Give the approximate chemical composition of petrol. Calculate the percentage of air in a mixture of air and petrol vapour, adjusted so that complete combustion may occur. If a gram of petrol liberates 11,400 gram-calories of heat on combustion, what would be the temperature of the gaseous products of combustion, the volume remaining constant, and no heat being lost?

Specific heat at constant volume of $CO_2 = 0{\cdot}172$
" " " H_2O (vapour) $= 0{\cdot}37$
" " " nitrogen $= 0{\cdot}173$

(2) If oxygen were mixed with petrol vapour in the correct proportion for complete combustion, what would be the temperature attained under the conditions described in Question 1? Could any practical advantage be gained by using oxygen instead of air?

(3) Prove, as simply and directly as you can, that the unbalanced weights in the moving parts of a reciprocating engine produce stresses which are proportional to the square of the speed (R.P.M.).

(4) Trace as closely as you can the connection between the size of the cylinder and the weight of the same, a constant horse-power being obtained by suitably varying the speed.

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PERSONAL ITEMS.

IN presenting the prizes at the Northampton Institute, on Friday, February 26th, the following remarks were made by Lord Kelvin. . . "I had great pleasure this evening in seeing something--only a small part—of the Electrical Engineering Department of this Institute. I hope to see something more of it. But I was greatly struck with the splendid arrangements in the Engineering Laboratory for giving scientific instruction in the most practical way to the students of the Institute. A large proportion of those students who are working in the Engineering Laboratory are already in practical work, earning their livelihood in various departments of electrical engineering. The Institute is of very great benefit to these students; to all classes of the workers—superintendents, foremen and workmen—it is of practical importance for the success of their work.

"When I think of the electrical knowledge of scientific men fifty years ago, and remember the discoveries during the last century—of Faraday, in England; of Henry, in America; and the great succession of workers who have followed them up to the present time--I cannot but wonder at the enormous advances made possible by their work. The brilliant discoveries which are now going on mark a progress which is more intense, more remarkable, more striking, at the beginning of the twentieth century, than it was during the whole of the nineteenth century. Many of these discoveries are in the realm of pure science, presenting no prospect of practical application. But what is to be thought of the scientific investigator who only looks for immediate practical application? The electrical discoveries of Faraday and Henry would never have been made if these men had asked who is going to benefit by them? Scientific men go on trying to discover the laws of Nature, trying to explain what has been seen. If practical applications follow, these are welcomed most of all by scientific discoverers."

IT is reported that the Worshipful Company of Goldsmiths have offered to transfer the Goldsmiths' Technical and Recreation Institute, New Cross, to the University of London; and that the authorities of the latter Institution have accepted the offer, subject to certain administrative alterations which are not yet made public.

THE Tenth Meeting of the Students' Engineering and Metallurgical Society was held at University College, Sheffield, on February 26th. Mr. H. E. Wadland read an interesting paper on mono-railways. The lecturer described the Cailletet, l'Artigue, Behr, and Langen systems, and gave a full description of the Listowel and Ballybunion Railway, Ireland, and the Barmen-Elberfeld Overhead Railway in Germany.

THE South London Photographic Society has awarded a bronze plaque for the Woolwich Polytechnic photographic exhibit.

ON Saturday, March 19th, Mr. F. E. Kennard, A.A.E.E., delivered an interesting lecture on Wireless Telegraphy. Amongst other experiments, Mr. Kennard showed that an eight-candle-power lamp could be lighted, by means of high frequency currents, through the human body.

THE attention of senior students who are likely to specialize in the sciences or application of electro-chemistry or chemical physics may be drawn to the fact that the Faraday Society has organised a special students' section. The subscription for students is £1 per year, and no entrance fee is required. Besides receiving all the publications of the Society, and being entitled to all the ordinary privileges of a full membership (excepting the right to vote), students are further entitled to receive, free of cost, the *Transactions of the American Electro-Chemical Society*, of which, at present, two volumes are published annually. Further particulars may be obtained from the Secretary, F. S. Spiers, 82, Victoria Street, London, S.W.

ON Thursday, February 4th, Mr. W. D. Seaton gave an interesting paper on the Production of Iron and Steel. After describing the methods of extracting the metals from the ores, the microscopical examination of the metals was dealt with.

AT a meeting of the Sheffield Society of Engineers and Metallurgists held at the Technical Department of the University College, on February 23rd, Mr. C. Strohmeyer, chief engineer to the Manchester Steam Users' Association, delivered an interesting lecture on Factors of Safety. It was argued that, owing to the limited knowledge on this subject at present possessed by engineers, refuge was taken behind high factors, with consequent waste of material. The necessity for exhaustive experiments, to lay the foundation for more accurate mathematical calculation, was strongly urged.

WE are glad to be able to inform our correspondent living near Rotherham that, in response to the complaint which appeared in our March issue under this heading, we have received a prospectus of the classes in the Arts and Science Department of the University College, Sheffield. Classes in organic chemistry have been held at the College since its opening, and students hailing from Rotherham and its vicinity are at present attending them.

MR. RUFUS E. MARSDEN points out that the subject of staircase construction, far from being passed over in technical classes, as stated by Mr. Jarvis, in his article "Planning, Setting-out and Making Staircases" forms a part of the syllabus of carpentry and joinery in the City and Guilds of London Institute examinations.

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RESULTS OF JANUARY COMPETITIONS.

THE results of General Competitions Nos. 1, 4, 5, 8 and 9, and Special Competitions I. and IV., were published in the March number. The results of the remaining competitions are given below.

GENERAL COMPETITIONS.

No. 2.—"HOW THIS MAGAZINE CAN BEST HELP STUDENTS."

FIRST PRIZE, £5.

Ernest O. Way, 14, Stormont Road, Lavender Hill, S.W.

SECOND PRIZE, £3.

Harold Slicer, 37, Crofton Road, Camberwell, S.E.

SPECIAL HONOURABLE MENTION :—

A. D. Holdcroft; S. Winterbottom; M. G. Tweedie; A. E. O'dell; R. G. Boyle; M. K. Babbage; Sydney G. Pipe; J. R. Pearson.

HONOURABLE MENTION :—

William Neagle; George Robert Wilkinson; John Norris; Edward Ingham; George Taylor; F. H. Rudd; H. J. Merriman; P. S. Aruf; Herbert J. Reeve.

No. 3.—"HOW THIS MAGAZINE CAN BEST ADVANCE TECHNICAL EDUCATION."

PRIZE, £10.

Geo. F. Butterworth, Holly Bank, Tottington, near Bury.

SPECIAL HONOURABLE MENTION :—

John Edbrooke; P. Abbott; B. Ingram; H. H. F. Hyndman.

HONOURABLE MENTION :—

Henry John; Geo. Grace; A. H. Stuart; George Randle; W. Burrows; A. P. Hill.

No. 6.—WIRELESS TELEGRAPHY.

PRIZE, £10.

A. G. Lee, Fairfield, Eaton Park Road, Winchmore Hill.

SPECIAL HONOURABLE MENTION :—

Thomas V. Staton; Walter Jamieson; W. H. Grinsted; G. H. Martyn; G. F. Tanner.

HONOURABLE MENTION :—

D. Fulton; H. B. Lee; J. Erskine Murray; J. W. Atkinson; Maurice A. Wood.

No. 7.—APPLICATION OF ELECTRIC POWER TO RAILWAYS.

PRIZE, £10.

R. E. C. Ihlee, 22, Parkfield Road, New Moston, Manchester.

SPECIAL HONOURABLE MENTION :—

F. Shaw; William J. Williams; H. A. Stewart; R. Borlase Matthews; S. Kirkwood; K. E. C. Schlesinger.

HONOURABLE MENTION :—

A. Camden Pratt; J. Saxton; John H. Corran; Harry H. Gordon; S. Piercy; Donald Smeaton Munro; R. M. Sheppard.

No. 10.—OPEN QUERY. EQUIPMENT OF ENGINEERING WORKSHOP.

PRIZE, £5.

Bernard Stephenson, 6, The Polygon, Eccles, Manchester.

SPECIAL HONOURABLE MENTION :—

David S. Paxton.

HONOURABLE MENTION :—

Percy Roslin; W. Millar; F. H. Bloomfield.

SPECIAL COMPETITIONS.

II.—DYES AND DYEING.

PRIZE, £5.

Miles Coupe, 46, Millerbarn Lane, Waterfoot, near Manchester.

SPECIAL HONOURABLE MENTION :—

G. M. Colbeck; T. E. Bradbury; J. B. Tattersfield.

HONOURABLE MENTION :—

J. F. Booth; J. Nochar; A. Wilson; F. Asquith; J. A. Craven.

III.—RADIUM.

This competition was exceedingly keenly contested, nearly all of the answers sent being of a very high order of merit. The awards are as follows :—

PRIZE, £5.

H. Harding, 47, Streathbourne Road, Upper Tooting, S.W.

SPECIAL HONOURABLE MENTION :—

H. Dobell; Cecil Hollins.

HONOURABLE MENTION :—

George J. Denbigh; H. E. Hurst; Alexander Caruth; M. K. Babbage; M. F. Levey; George Pugh; John Johnston; H. G. Wood; B. C. Wallis.

V.—TEXTILE DESIGN AND MANUFACTURE.

PRIZE £5.

W. R. Horsham, 24, Prosperity Street, Camp Road, Leeds.

HONOURABLE MENTION :—

Lister Smith; J. T. Fletcher.

The Prize of £3, for the **BEST SINGLE ANSWER** in the five competitions, has been awarded to Alexander Sanderson, Brookfield House, Millfield Lane, Highgate Rise, N., for his answer to Question 1 on "Radium."

The results of our February Competitions will appear in our May number.

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CLAYTON BEADLE, F.C.S.

Photo by George Newnes, Ltd.

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TECHNICS

A MAGAZINE TO AID TECHNICAL PROGRESS.

VOL. I. MAY, 1904. NO. 5.

PROGRESS OF SCIENCE AND TECHNOLOGY.

WHILE Blondlot and Charpentier continue their researches on N rays, apparently unmoved by hostile criticisms, other observers have been unable to verify even the simplest experiments these investigators have described. Mr. Leslie Miller has made it possible for anyone to try the fundamental experiments on N rays, by putting on the market a zinc sulphide screen mounted on a suitable handle. A lens is placed in front of the screen, and serves to protect the latter from damage. To use this outfit, the screen must be exposed to the light from a burning piece of magnesium ribbon, and then taken into a dark room. The person who wishes to make observations should not be present during the exposure, as the bright light from the magnesium renders the eye insensitive for some time afterwards to feebly luminous objects. Most persons, on observing the screen in the dark, can readily perceive marked increases and diminutions in its luminosity; but these occur equally well when no contracted muscle or nerve centre is near the screen. This phenomenon appears to be due to some peculiarity or peculiarities of the eye. One point which can be easily noted by an attentive observer is, that it is difficult to keep the eye properly focussed on the small luminous patch of zinc sulphide. When viewed steadily for some time, the patch appears to become double, obviously owing to the relaxation of the muscles which affect the convergence of the eyes in binocular vision. In some cases, on steadily watching the spot of light, it entirely disappears, to reappear after momentarily closing the eyelids. Other interesting phenomena may also be readily observed. On moving the screen slowly across the field of vision, a peculiar scintillating effect is produced. But these observations, however interesting they may be, do not serve in any sense to verify the existence of N rays.

N Rays

SOME of the above observations may be easily explained. König has proved that crepuscular vision (*i.e.*, vision by the aid of very faint light) is due to a chemical change in the visual purple, a pigment present only in the rods of the retina. The rods are distributed throughout the retina, except in the *fovea centralis*. When a small object is viewed, the eye is adjusted so that the ocular image is formed on the *fovea*. The absence of rods from the *fovea* renders that spot practically blind to feeble light; this accounts for the well-known fact, first observed by Arago, that a small, faint star appears much brighter when the eye is directed toward a point of the heavens at some distance from it, than when the star is viewed directly. Now if we attempt to watch a small, feebly luminous patch in a dark room, the eye is naturally adjusted so that the image falls on the *fovea*: consequently the luminosity of the patch appears to partially or wholly disappear. After a short time, the eye is sure to wander a little, with the result that the image now falls on a part of the retina where the rods are plentiful, and crepuscular vision is proportionately acute. As a result, the patch suddenly appears to increase in luminosity. Of course, Charpentier is quite aware of these phenomena; indeed, he has carried out researches on this subject, and has found

Crepuscular Vision and N Rays

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that, in a dark room, two small, feebly luminous objects may appear equally bright, although one is really nine times as bright as the other; while differences of one or two per cent. can easily be detected in large objects under similar conditions. But in spite of the high reputations of Blondlot and Charpentier, it appears to be impossible to place implicit trust in the existence of N rays until the results obtained by these investigations have been confirmed by independent observations.

Recent Steam Turbines of Large Capacity

Five years ago, no steam turbine-driven electric generating sets of over 500 kilowatts capacity had yet been built. A 5,000 k.w. vertical Curtis turbine set, built by the General Electric Company at Schenectady, is now in operation in Chicago*; several 5,500 k.w. horizontal Westinghouse sets are approaching completion at Pittsburg, and a 6,500 k.w. Parsons set is being built by Messrs. Brown-Boveri and Co. of Baden, Switzerland. This latter set will be the largest in the world, and its makers have guaranteed a full load steam consumption of less than seven kilograms per kilowatt-hour. Indeed, they have already obtained this economy in a 3,000 k.w. set recently installed.†

This rapid progress is due, not so much to the excellent economy of the steam turbine (for this is approximately equalled by the best piston engines), but chiefly to the low first cost. A turbine set, including the electric generator, costs no more than a slow-speed steam engine alone. As the electric generator costs half as much as the slow-speed engine by which it is driven, the total outlay for generating plant is reduced by one-third by means of the steam turbine. Moreover, the steam turbine sets occupy much less than half the space required by the piston engine sets, and they require a relatively very small outlay for foundations. These considerations introduce great economies in the outlay for the power house. The steam raising plant is, however, about the same for both cases, and the condensing outfit must be more expensive in the case of the turbine, owing to the fact that the economy of the steam turbine is greatly dependent on a high vacuum. For the Curtis turbine, it is found that the steam consumption is reduced one and one-half per cent. for every one per cent. improvement in vacuum, for vacuums above 640 mm. On the other hand, it is claimed‡ as a feature of the Westinghouse turbine, that it can also show an admirable performance with a poor vacuum and low boiler pressure. This is certainly not the case with most types of steam turbines. An excellent feature of the Curtis turbine is that the steam consumption per kilowatt-hour of output increases but slightly with decreasing load. Thus, in a 500 k.w. Curtis turbine set, the economy with a steam pressure of 10 kgs. per sq. cm., 64° C. of superheat and a 95 per cent. vacuum, was 8·5 kgs. of steam per kilowatt-hour, and at one-quarter load this figure had only increased to 10·2 kgs., *i.e.*, by 20 per cent.§ In many published tests on other turbines, the consumption at one-quarter load is at least 40 per cent. higher than the full load consumption; in fact, this has heretofore been one of the weak features of the steam turbine. For good piston engines it may be said that the steam con-

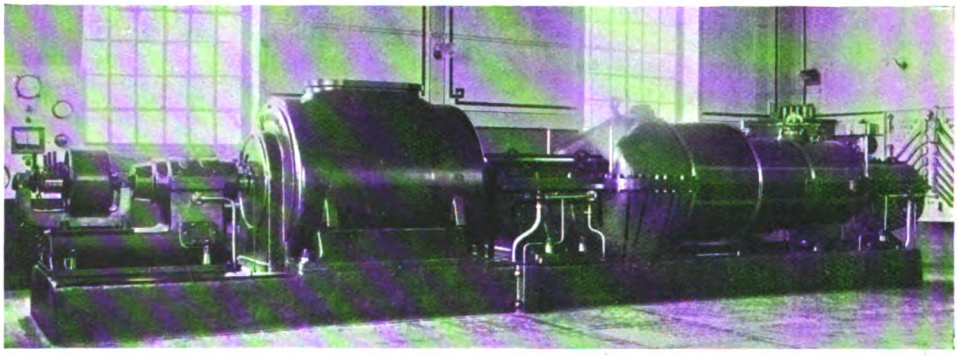

Fig. 1.—Brown-Boveri-Parsons Turbo-Generator Installed at Rheinfelden.

* "Proc. Am. Street Railway Assoc.," pp. 63–70, 1903-1904.

† See "Technics," February, 1904, p. 110.

‡ *The Electric Club Journal*, March, 1904, p. 93.

§ *Electrician*, February 5, 1904, pp. 596 to 598.

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sumption per kilowatt hour at one-quarter load, varies from 20 per cent. to 30 per cent. more than at full load, according to type and capacity.

The 5,000 k.w. vertical Curtis turbine at Chicago is about 7·6 meters high and 4·3 meters in diameter, and the weight, including the electric generator, is about 180,000 kgs., or 36 kgs. per kilowatt of rated output. It occupies a net floor space of $\frac{\pi}{4} \times 4{\cdot}3^2 = 14{\cdot}5$ square meters. It thus has a rated output of 345 k.w. per square meter floor space.

For the horizontal 5,500 k.w. Westinghouse turbine, the length, width, and height above floor, of the whole set, including electric generator, are, in meters, respectively 14·3, 4·9, and 4·2. The net floor space is thus 14·3 × 4·9 = 70 square meters, and the rated output per square meter is thus but 79 k.w. It has, however, the advantage over the vertical type Curtis turbine, that the turbine and the electric generator are both thoroughly accessible, whereas in the latter the turbine is located underneath the generator, rendering some parts of the turbine more difficult of access.

The 6,500 k.w. Brown-Boveri-Parsons set has a height of 3 meters and an overall length of 18 meters.

But in all of these three cases, the net floor space is so much less than would be required by a piston engine, that the difference between them is of less importance than might at first sight appear; for when a suitable amount of floor space is allowed between and around the sets, the percentage difference in gross dimensions of engine room is not great for these different types of steam turbine.

These large turbines all drive alternating current generators. No satisfactory continuous-current generator for more than 500 k.w. rated output has yet been standardised for such high speeds, and it is hardly worth while to employ turbines in smaller units than 1500 k.w. each, for their advantages over the piston engine are far less marked in small sizes.

A great deal has been said and written about the untrustworthiness of the steam turbine. In view of the recently announced decision to use turbines for the propulsion of the two new Cunarders now building, there can hardly be any further question as to the confidence felt in well-informed quarters with regard to the trustworthiness of the steam turbine.

Two Recent Steam Turbine Plants, of the Brown-Boveri-Parsons System

(By our Berlin Correspondent)

EARLY in November, 1903, a steam turbine designed for an effective output of 1,700—2,000-h.p., direct-coupled to a 1,200—1,400-k.w. generator for 3-phase alternating current, was installed in the Steam Central Station of the Rheinfelden (Switzerland) Power Transmission plant. This turbo-alternator is operated by steam superheated to 260-270° C., at a pressure of 12·5 atmos., in connection with surface condensers. The whole group, working at 1,500 revs. per minute, can be thrown in parallel, either with the Rheinfelden hydro-electric plant, or with the Beznau central station, at a distance of 25 km., intended to supplement the Rheinfelden station.

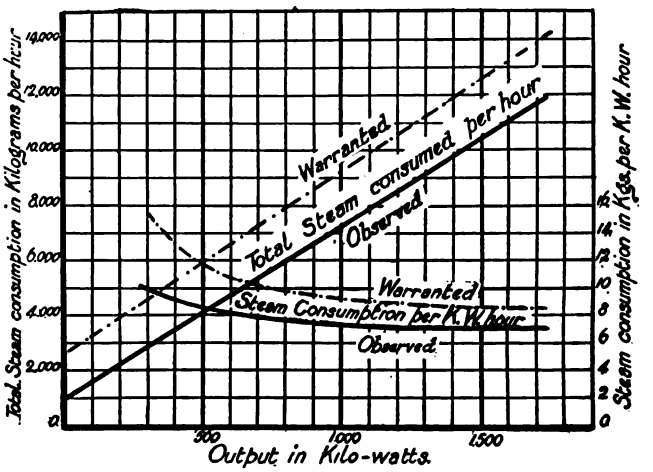

FIG. 2.—STEAM CONSUMPTION FOR BROWN-BOVERI-PARSONS TURBO-GENERATOR SET.
STEAM AT 12·5 ATMOSPHERES PRESSURE AND 260–270° C.

The official tests made in Rheinfelden between December 12th and 16th have given most satisfactory results; the accompanying diagram represents the steam consumption obtained with a vacuum of 96 per cent. in the condenser; and affords, at the same time, a comparison with the warranted values of the steam consumption. At the full load of 14,000 k.w. the steam turbine will consume 6·95 kg. of steam per k.w. hour. The power required for driving the condenser pump varies between 12 and 22 k.w.

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Under normal working conditions, the steam turbine at no load and with non-excited alternator, uses 830 kg. of steam per hour, which figure is reduced to 600 on disconnecting the generators.

The steam consumption of the turbine at no load, including losses due to the operation of the regulator, oil pump, etc., would thus not be more than 6 per cent. of the consumption in the case of a load as high as 1,400 k.w. The consumption of steam obtaining without load, but with excited alternator, being 1,118 kg. per hour, is also extremely low.

Furthermore, it is interesting to note that, on deducting the amount of 1,118 kg. necessary at no load from the total consumption of steam, the value of 6·2 kg. per k.w. hour is observed with striking constancy for the different loads. Thus the constant losses being once overcome, the engine proves equally satisfactory for all loads.

Experience further goes to show that, independently of the alternator, the turbine can work under much higher loads than the warranted figures, the load being readily increased up to values as high as 3,000 h.p. In the case of the possibilities of the turbine being fully utilised, the figures obtained for the consumption of steam would be even more advantageous than those above recorded.

At about the same time that the above system was put into operation in Rheinfelden, a turbo-alternator of 900–1,100 k.w. was installed in the Usine de Puteaux of the Compagnie d'Electricité de l'Ouest Parisien, Paris, working at 1,600 revs. per minute under a steam pressure as high as 10 atmos., and with steam at 250° C superheat.

The alternator, direct-coupled to the turbine in conjunction with its exciting machine, generates two-phase alternating current, at a tension of 2,800 volts.

As regards the experience gained in working on this group, the following data were recorded in the report of the trials made on delivery :—

Load in k.w. . . .	1,140	984	688
Steam temperature .	257°C	252°C	241°C
Admission pressure of steam, in atmospheres	10·3	10·3	10·3
Vacuum of condenser in mm.	684	682	694
Steam consumption, per k.w. hr. at the terminals of alternator	8·4	8·4	9·8

The condenser requires in operation 15 to 18 k.w. The regulation of this turbine is extremely rapid and safe, the variation in the speed amounting only to 1·3 per cent. as the load is diminished from 930 k.w. to zero; while a diminution of load from 470 k.w. to zero produces a speed variation so low as 0·8 per cent.

The Use of Superheated Steam

In a paper recently read before the Institution of Electrical Engineers at Birmingham, Mr. R. K. Morcom made some interesting remarks on the advantages of using superheated steam for engines. He stated that in a piston engine properly designed to run with superheated steam, full advantage is taken of the increased economy, with but little extra trouble in running. It is only when an engine is unsuited for use with superheated steam that troubles arise. Mr. Morcom also stated that it is a mistake to suppose that an engine designed to run under superheat conditions is unsuited for use if the temperature of superheat falls. An engine designed to work with about 140° C. superheat was run with dry steam at saturation temperature, and was found to be only 2·1 per cent. less economical than when fitted with pistons and valves designed for these conditions.

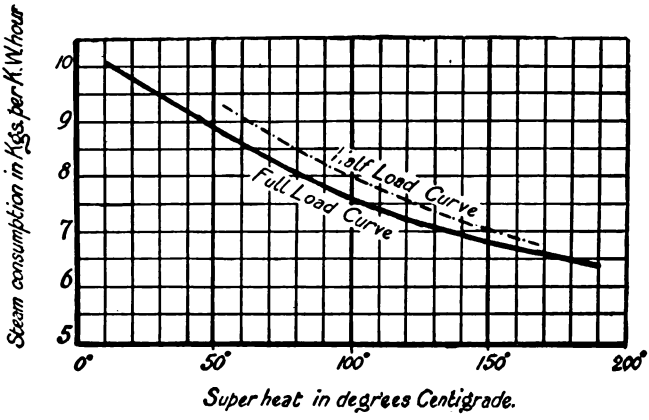

FIG. 3.—STEAM CONSUMPTION FOR DIFFERENT DEGREES OF SUPERHEAT.
Steam Pressure 10·5 *Atmospheres. Vacuum* 90 *per cent.*

Fig. 3 comprises curves drawn from data due to Mr. Morcom. The curves refer to trials of a three-cylinder triple engine of 200 k.w. capacity. The trials were run on

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the brake at 160 lbs. steam pressure and 26 in. vacuum in the condenser. It will be seen that both on full and on half load a most remarkable gain in steam consumption is obtained by using highly superheated steam. On a given type of engine the curves obtained are very similar for all sizes.

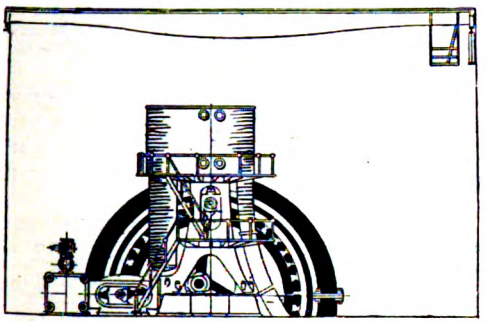

FIG. 4.—5,000 K.W. CYLINDER ENGINE GENERATOR SET.

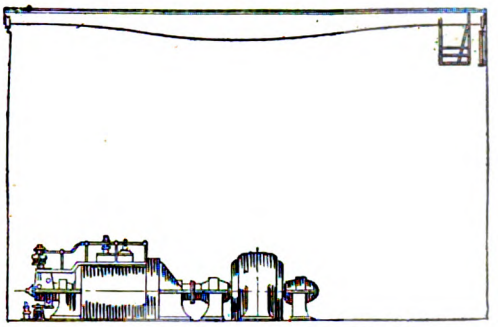

FIG. 5.—5,000 K.W. TURBO-GENERATOR SET, PARSONS TYPE.

Superheating involves extra cost in lubrication and in fuel. The increased cost of oil for cylinder lubrication amounts to about 0·04*d.* per 100 h.p. hours, and is therefore a small item. The cost of fuel is more important, but with steam superheated to about 320° C. a net gain of 25 per cent. may be anticipated.

In the discussion which followed on Mr. Morcom's paper, Mr. Henry Lea stated that when the piston and valves of an engine are at all leaky, superheating the steam 20° or 30° C. produces an enormous reduction in steam consumption. In some tests made with steam at 60 lbs. per square inch, 22° C. superheat reduced the amount of leakage by 45 per cent.; very little further reduction was obtained by increasing the superheat to 55° C. Thus the greater economy due to the use of superheated steam may be due to two distinct causes:—In the first place, a thermodynamical advantage is obtained, which is irrespective of the amount of leakage. In the second place, leakage is reduced, and the efficiency correspondingly increased. Mr. Lea mentioned a 200-h.p. high-speed engine, known to be in a leaky condition, which was increased in efficiency by just 100 per cent. when the steam was superheated through 10° to 15° C.

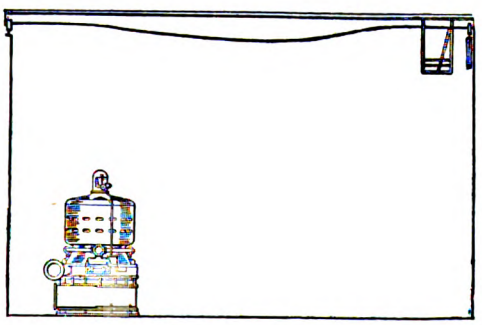

FIG. 6.—5,000 K.W. TURBO-GENERATOR SET, CURTIS TYPE.

ALTHOUGH the space occupied by a generator set is not the condition which, in most cases, determines its suitability, it is yet a feature which deserves attention. In large towns, ground rent is generally high, and economy in floor space must be taken into consideration. The relative sizes of different types of generator sets are strikingly shown in Figs. 4, 5, and 6. Each set represented has a capacity of 5,000 k.w., and all are drawn on the same scale. Fig. 4 represents the end view of a dynamo driven by a piston-engine. Fig. 5 represents a turbo-alternator set of the Parsons type. Fig. 6 represents a turbo-alternator set of the Curtis type. It seems scarcely credible that the pigmy set represented in Fig. 6 should possess the same capacity as the piston-engine and dynamo represented in Fig. 4. A further point of importance is that this gain in space is obtained without sacrifice of efficiency.

Space Required for Generator Sets

THE increase in the use of steam power in Prussia, since April 1st, 1902, is shown by the following table, for which we are indebted to the Zeitschrift des Vereins Deutscher Ingenieure. This table does not

The Use of Steam Power in Prussia

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include locomotives, or any boilers and engines used by the Army and Navy. The marine boilers and marine engines recorded are exclusively used for propelling the ships, while these contain further 698 steam boilers, with 1962 steam engines for the operation of steam dredgers, cranes, etc. The latter are, according to their design, recorded together with stationary or transportable steam boilers and engines:—

	1902.	1903.	Increase. Absolute Increase.	Increase. Per Cent.
Stationary steam boilers	72,098	73,181	1,083	1·50
Stationary steam engines	77,583	79,257	1674	2·16
Transportable steam boilers	22,259	23,211	952	4·28
Steam engines connected thereto	21,612	22,556	944	4·37
Inland steamships	1,757	1,814	157	8·92
Steam boilers thereon	1,984	2,047	63	3·16
Steam engines thereon	1,946	2,018	72	3·70
Steam ships	502	535	33	6·57
Steam boilers thereon	675	722	47	6·95
Steam engines thereon	533	571	38	7·15
Marine boilers total	2,659	2,769	110	4·14
Marine engines total	2,479	2,589	110	4·44

The Law of Dalton-Henry in connection with the absorption of Radioactive Emanation

In a paper read before the Freiburg i. B. Society of Naturalists, in April, 1903, Prof. F. Himstedt showed that air, on being blown through water, will assume an electric conductivity up to 100 times greater than the initial value. These experiments have recently been continued by Freiherr Rausch von Traubenberg with the Elster and Geitel dispersion apparatus, the results being as follows:—

(1) Cistern water will lose its ionising power, which may be restored to it by air blown through it by means of a water blast.

(2) All the liquids examined are susceptible of being activated artificially, this being especially true in the case of hydrogen carbide.

(3) The ionising power of water appears to be due to a radioactive emanation dissolved in water, and following, like a gas, the law of Dalton-Henry.

(4) The absorption coefficients of the various liquids with respect to this radioactive emanation are calculated from the equation governing the absorption of gases.

(5) Radium emanations seem to behave with respect to absorption by liquids, in a way quite analogous to the emanation from cistern water.

A New Mineral from Ceylon

During the examination of minerals sent by the Government of Ceylon to the Imperial Institute, Professor Dunstan has found one existing in small black cubical crystals, which occurs in the refuse from gem washings near Balangoda, in the Sabaragamuwa Province. In a letter printed in *Nature* of March 31st, Professor Dunstan states that the specific gravity of this mineral is 9·32, and that its chemical constitution is as follows:—

		Per cent.
Thorium oxide	($Th O_2$)	76·22
Cerium oxide	($Ce O_2$)	8·04
Lanthanum oxide	($La_2 O_3$·$Di_2 O_3$)	
Zirconium oxide	($Zr O_2$)	trace
Uranium oxide	($U O_3$)	12·33
Ferric oxide	($Fe_2 O_3$)	0·35
Lead oxide	($Pb O$)	2·87
Silica	($Si O_2$)	0·12
		99·93

This mineral is not pitchblende, since it contains such a small percentage of uranium. The occurrence of more than 75 per cent. of thoria in it would render it interesting from a scientific point of view, no other mineral being known which contains so large a proportion of this substance. At the same time, the increasing demand for thoria, in connection with the incandescent gas-mantle industry, would render this mineral of great commercial value. Professor Dunstan proposes to term it *thorianite*.

A New Source of Helium

In a letter communicated to *Nature* of April 7th, Sir William Ramsay states that at the beginning of February he obtained five cwt. of the mineral described by Professor Dunstan. He has found that on fusing this mineral with hydrogen potassium sulphate, 9·5 c.cs. of helium can be obtained per gram of the mineral. About twelve cubic feet of helium have already been obtained in this way. He also states that the mineral contains practically no thorium—less than 1 per cent. The oxalate is almost completely soluble in excess of ammonium oxalate—a reaction which excludes thorium and the cerium group, but which points to zirconium. But although zirconium is undoubtedly present, this is not the main constituent. It appears that at least one new element

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is present in large quantities. The most soluble portion possesses an equivalent of 44·7; and assuming the new element to be a tetrad, it would fill a gap in the periodic table between cerium and thorium. One at least of the new elements present (supposing that there are more than one present) will probably have an atomic weight of 177, preceding tantalum (182·5) in the horizontal row of the periodic table. The spectrum of the new body or bodies is now being mapped out.

The mineral is radio-active, and the period of decay of the emanation appears to indicate the presence of a radio-active element closely resembling thorium X, but not identical with it.

Technical Education in America

THE present instability of educational schemes in the United Kingdom is doubtless the cause of the very close scrutiny which foreign educational systems are now receiving. This scrutiny has produced various impressions on different observers; and in no case has greater diversity of opinion been expressed than with regard to American educational methods. On one point alone are all observers agreed: that is, on the appreciative attitude of American employers toward those who have undergone a sound technical and scientific training. A report on *Some Features of American Education*, by Robert Blair, M.A., B.Sc., recently issued by the Department of Agriculture and Technical Instruction for Ireland, contains much valuable matter for the formation of a correct estimate of trans-Atlantic educational methods. The letters from leading business men in the States, printed on pp. 143–161 of the report, bear strong testimony to the interest which American industrial leaders take in this subject. The following extract from the letter of Professor E. Sweet, Syracuse, New York, possesses considerable interest.

"It is now forty years since I lived in England, but from what I can remember of the English lad of twelve or thirteen years of age, and what I know of the American boy of, say, fourteen years of age, the English lad was trained, and well understood the subjects he studied, while the American boy of to-day has a crude idea of too many subjects. The English lad was disciplined; the American boy is hardly controllable."

* * * *

"The two undesirable features about our school and college systems are the examinations and the diplomas. The examinations are held to determine the relative ability of the students, and are absolutely unreliable. The diplomas inspire the students to cram for examinations rather than to get at the bottom of the subjects they are studying. The Trade School need not be hampered by these things.

"I found that of my students at Cornell University, those who did not graduate or aim to, proved in the end to soonest gain prominent positions, and also to hold them, and, in the main, keep ahead."

* * * *

"There needs to be from ten to a hundred workmen to every engineer, and yet we have hardly one trade school to a hundred engineering colleges."

Evening Class Students

THOSE who decry our national education in comparison with the methods in vogue abroad, might be reminded that we are practically the only country possessing a well-organised system of classes for evening students. Those who have had little or no experience of the work at present carried on in these classes, are only too apt to speak disparagingly of the results obtained. But, in truth, we have nothing to be more proud of than our system of evening class education. Of course, a student attending classes for only a few hours a week cannot be expected to cover so much ground as one whose whole time is devoted to study. But those who have had experience of both systems can testify that the progress of an evening class student, per hour spent in class, is more remarkable than that of the ordinary day student. Moreover, an evening class student is not obliged to compress the whole of his educational career into two or three years; most good institutes have numbers of students who follow up their studies year after year, ultimately attaining a standard of knowledge which is far and away above that of the ordinary day student. To mention only two instances: at the Municipal Technical School, Manchester, and the East London Technical College, evening class students of mathematics frequently reach a standard of knowledge which would qualify them to obtain a high position in the mathematical tripos of Cambridge. Mr. Hulme's article, printed elsewhere in this issue, draws attention to the favourable opinion of our evening class system held by many of the most enlightened American industrial leaders.

Surface Structure of Solids

AN account of a lecture by Mr. George Beilby, published in a recent number of the *Journal of the Society of Chemical Industry*, contains an interesting discussion of observations made on the surface structure of solids,

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and especially of metals. A file-mark on a brittle metal presents to the eye a scratched and rugged appearance; but when the scale of operations is reduced and the scratches made by rubbing lightly with the finest emery paper are examined under a high power, the roughness of the furrows is found to have disappeared, and the scratches present an appearance similar to that of a freshly-painted surface, from which the marks of the brush have not yet disappeared; the metal appears, in fact, to have acted like a liquid, and been drawn into smooth outlines under the influence of surface-tension. This view is confirmed by the behaviour of the metal when polished; if gently rubbed across the direction of the previous scratching, the furrows become covered, but are not obliterated, since they can be reproduced by etching the surface with weak acids. During the polishing, a film, behaving for the time as a liquid, appears to be spread over the surface of the metal, covering over all irregularities, and even sometimes forming a membrane across the top of minute pits in the metal. Similar changes are noticed when glass is scratched with a diamond point, and when a freshly broken surface of Iceland spar is stroked with a soft wash-leather; and the phenomena appear to be absolutely general. It has long been known amongst technical workers that there is a sharp difference between grinding and polishing or burnishing, and the explanation now given is, that the latter processes consist in bringing about a flow of the surface of the material, whilst grinding acts mainly by removing projecting particles. Taken in conjunction with the experiments of Professor Adams on the flow of marble, of the late Professor Roberts-Austen on the diffusion of gold through solid lead, and of Stead on the segregation and migration of the constituents in solid steel, the results now recorded call for a revision of the generally-accepted ideas of the essentially rigid character of crystalline solids.

The Berlin Telephone System

ACCORDING to the latest returns, the number of subscribers to the Berlin Telephone system has reached the enormous figure of 73,000. This means an increase of about 10,000 in the course of last year. Of the above total, about 11,000 subscribers hail from the suburbs, Berlin itself being represented by about 62,000, *i.e.*, 6,000 subscribers more than last year. The largest Berlin telephone exchange is the main telephone office, comprising 12,340 connections.

Optical Identification of Alkaloids

P. KLEY places a small crystal of the alkaloid, with a liquid of known refractive index, on the object glass of a polarising microscope, and progressively changes the liquid until one having the same index as the crystal is found (as shown by the loss of identity of the contour of the crystal). This method obviates the determination of the crystalline form and angles of the optical axes, etc. (*Rec. trav. Chim. Pays Bas* 22, 367; through *Journ. Soc. Chem. Ind.*)

The Electrolytic Preparation of Iodoform

BY electrolysing potassium iodide in presence of acetone, with low anode current density and high cathode current density, excess of alkali being neutralised as fast as formed with either carbon-dioxide, hydrochloric acid, hydriodic acid or iodine, and working at ordinary temperature, J. E. Teeple produces almost theoretical yields of iodoform. (*Journ. Amer. Chem. Soc.*, 26,170.)

The Determination of Formaldehyde

C. KLEBER titrates formaldehyde with a solution of sodium bisulphite (treated with a solution of pure sodium hydrate until the odour of sulphurous acid disappears) adjusted so that 30 c.c. neutralise 50 c.c. of normal sodium hydrate. (*Pharm. Rev.* 22.94.)

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THE FIBROUS CONSTITUENTS OF PAPER.

No. I.—Esparto.

By CLAYTON BEADLE, F.C.S.

Illustrated by Photo-micrographs, prepared by John Christie.

Fig. 1.—Esparto Grass.

THERE is no English literature worthy of the name devoted to the subject of Esparto, in spite of the high technical importance and the almost unique position that this substance occupies as a raw material in the manufacture of the highest qualities of printing papers. What fragmentary literature there is upon this subject, is to be found scattered here and there in the few text-books devoted to the manufacture of paper; and these give little else than recipes for the boiling and bleaching of Esparto, which processes vary in different mills according to peculiar conditions and requirements. The only monograph on Esparto of which the writer has any knowledge is the very excellent treatise in the French language, compiled by Monsieur L. Trabut, *Professeur à l'École de Médecine* of Algiers, and to whom the writer is much indebted for the instructive illustrations exemplifying the culture and structure of the Esparto fibre used in connection with this text. As no photo-micrographs have before been reproduced for publication, those accompanying this article should be of more particular interest.

There is only one real Esparto grass available for paper-making, *viz.*, *Stipa tenacissima*. This should be noted, since writers frequently name other closely-allied grasses as being available for the purpose, such as *Lygeum spartum*, which is not true Esparto. The dry leaf of this plant has been used, from early historical times, for making such articles as carpets, sandals, ropes, baskets, nets, sacks, and as a substitute for horsehair, etc.

In 1839 attempts were made to utilise Esparto in the manufacture of paper. Mr. Thomas Routledge exhibited the fibre at the 1851 Exhibition. Its real introduction for paper-making is said to date from 1852. In "Chambers' Encyclopædia," 1891 edition, in the article devoted to Esparto, it is stated that the Journal of the Society of Arts, issue of November 28th, 1856, was printed upon Esparto paper; and in the obituary notice of Mr. Routledge, appearing in the Society of Arts Journal, it is stated that the above issue was printed upon paper made from Esparto at Eynsham mills. Curiously enough, there is no reference in the journal itself of this fact. The writer, through the courtesy of the Secretary of the Society of

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IMPORTATION OF ESPARTO INTO THE UNITED KINGDOM DURING THE LAST 10 YEARS (1894-1903).

From	1894.	1895.	1896.	1897.	1898.	1899.	1900.	1901.	1902.	1903.	Average for 10 years.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Spain. . .	57,177	60,629	67,715	61,828	55,612	56,926	50,520	47,050	56,777	49,879	56,411
Algeria . .	73,562	68,979	70,251	81,486	83,701	84,806	90,869	67,940	63,663	63,974	74,923
Tunis. . .	14,379	11,660	15,604	17,499	25,532	16,490	19,568	33,639	30,900	32,456	21,782
Tripoli . .	39,787	44,968	33,662	43,596	32,376	49,266	39,198	45,205	46,925	32,716	40,770
Other Countries	55	172	46	170	120	116	125	103	27	64	100
	184,960	186,408	187,278	204,579	197,341	207,604	200,280	193,937	198,292	179,089	193,986

Arts, has been supplied with a copy of the issue in question, and finds it to be a rag paper. There may, however, have been a few copies of the issue printed upon Esparto distributed among members of the Society. Up to 1861 or 1862, Routledge, on his own statement, was the only paper-maker using Esparto in England; when the American War broke out, entailing a short supply of cotton, Esparto began to come into general use. From that time until about 1890 the consumption of Esparto rapidly increased. Great Britain, to this day, is practically the only user of it, although her Colonies greatly appreciate paper made from it.

Esparto grass is shipped from Spain, Algeria, Tunis, Tripoli, and formerly from Morocco, with a small amount from other countries. Esparto grass grows in clumps: it requires very little cultivation: does well with very little rain; and flourishes on a rocky and sandy soil. In its wild state it chiefly grows on inland mountain plateaus. It appears to favour a lime soil, and does badly on clay. The best climate for the growth of Esparto is that of the sea coast, and of moderate altitudes. The Esparto zone may be said to run from 32° to 41° North latitude: it includes the southern part of Spain and the northern rim of Africa. Esparto is indigenous throughout this zone at altitudes ranging from the sea-level to about 3000 feet above it.

FIG. 2.—THE ESPARTO PLANT (*Stipa tenacissima*).

Space will not permit us to go into the subject of harvesting and collecting the grass. For information on this subject one could not do better than read a paper by Robt. Johnston on Esparto, appearing in the Journal of the Society of Arts, December 22nd, 1871. There is, however, no literature on this subject of recent date. Suffice it to say that the portion of the plant available for paper-making is the long lance-shaped leaf, two or three feet in height, which, when the plant is ripe, becomes folded tightly up towards the centre, with the ribs and fine silicious hairs innermost, thus presenting the general appearance of a coarse wire.

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At the time of harvesting, the dry leaf is pulled from its sheath by the aid of a hand instrument called the "batonnet," after the manner of the illustration, Fig. 3. Each clump yields an annual harvest in this way, and will last from 30 to 50 years. Unless the grass is gathered at the proper time, it yields a very unsatisfactory fibre, as in its green state it gives a semi-transparent appearance and objectionable vegetable-like character to the paper made from it.

Root-ends, accidentally pulled up and included in the harvested grass, very much detract from the value of the latter for paper-making. These have to be removed, either by hand or by means of a screen, during the process of preparation and manufacture into pulp. Hence the necessity for careful "pulling" of the leaf from the sheath, so as to leave all root-ends in the ground. The pulled grass is allowed to dry in the sun for some days. During drying, it loses upwards of 40 per cent. of its weight.

After harvesting it has to be very carefully picked over to remove root-ends, black fibres, etc.: sorted out into different grades: baled; and hydraulic pressed.

When shipped loose in bundles, it occupies from four to five "tons measure" to every ton in weight: when packed into bales with iron hoops it is reduced to about half the volume. Taking forty cubic feet as equal to one "ton measure," then $40 \times 5 = 200$ cubic feet per ton, and $\frac{2240}{200}$ lbs. $= 11{\cdot}2$ lbs. per cubic foot, packed without pressure; but under hydraulic pressure, it will compress to $22\frac{1}{2}$ lbs.

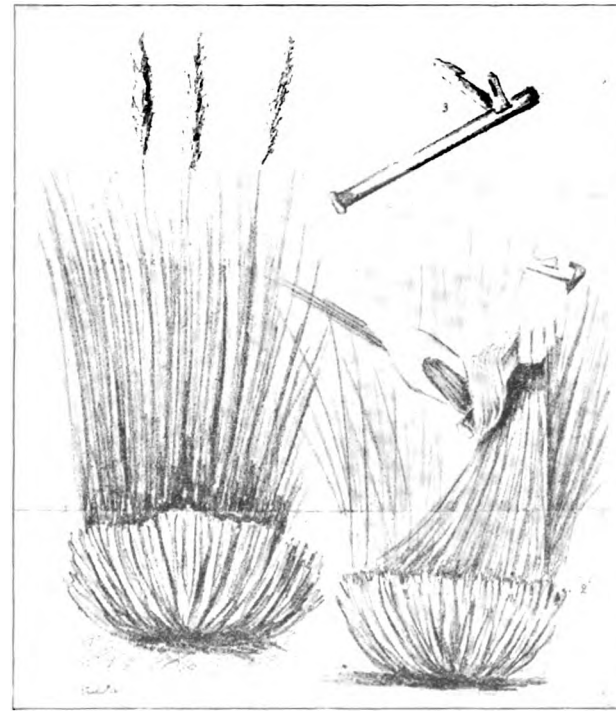

FIG. 3.—TO ILLUSTRATE THE METHOD OF "PULLING" ESPARTO GRASS BY THE AID OF THE "BATONNET."
(*The "batonnet" is shown separately at* 3.)

to the cubic foot. On account of the bulky nature of Esparto, the freight charges to some countries render its price prohibitive; but a leading factor in determining the cost of Esparto pulp is the price of caustic soda and bleaching powder, which have to be consumed in considerable quantities.

In the state of dry baled grass the Esparto is delivered at the paper mill. The composition, by analysis, of dried Esparto grass is, after Fremy:—

Alcoholic extract	3·35 per cent.
Aqueous „	9·95 „
Pectose substances	7·80 „
Vasculose and cutose	17·80 „
Cellulose	46·00 „
Ash	3·20 „

Esparto resembles straw and other cereals in that it contains considerable quantities of silica, which help to give rigidity to the dried leaf. This is removed as sodium silicate in the boiling process.

PARTICULARS OF ESPARTO BOILINGS.
(*After Beveridge.*)

	Variety of Esparto.	
	Spanish.	Tripoli.
Weight of charge	50 cwts.	50 cwts.
Gallons of caustic lye per charge	1,570	1,570
Lbs. of 60 % caustic soda per gallon of lye	0·509	0·649
Total lbs. of dry 60 % caustic soda per charge	900	1,020
Lbs. of 60 % caustic soda per cwt. of Esparto	18	20·4
Steam pressure maximum	20	20
Time under pressure in hours	2½	3
Yield of unbleached air-dry (10 % water)	43/45%	41/42%

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The grass undergoes chemical treatment in the paper mill, by boiling under from 20 to 40 lbs. pressure, for from 2½ to 5 hours, in contact with a solution containing about 6 per cent. of caustic soda, and subsequent bleaching with bleaching powder, when practically the whole of the ingredients are removed, with the exception of the "cellulose" of which the bleached paper-making fibres consist.

The capacity of the Esparto boiler in use was 540 cubic feet (8 ft. 9 in. diameter by 9 ft. high), and of the usual "vomiting" type. The space within the boiler occupied by 50 cwts. of the grass after "cooking" and draining was 300 cubic feet.

The reasons for considerable variations in conditions of boiling are due largely to the individual requirements of different mills. It stands to reason that the more thoroughly the grass is boiled, the less will be the consumption of "bleach." In this the paper-maker is in some measure guided by the relative prices of bleach and caustic soda. Some mills add more soda than is absolutely necessary for the boiling, so as to retain about 5 per cent. in excess, which ensures a more ready flow of the concentrated liquors through the evaporator. The caustic liquors are evaporated to dryness, and incinerated for "ash," which is causticised with lime and used again. The percentage of soda recovered in a well-appointed

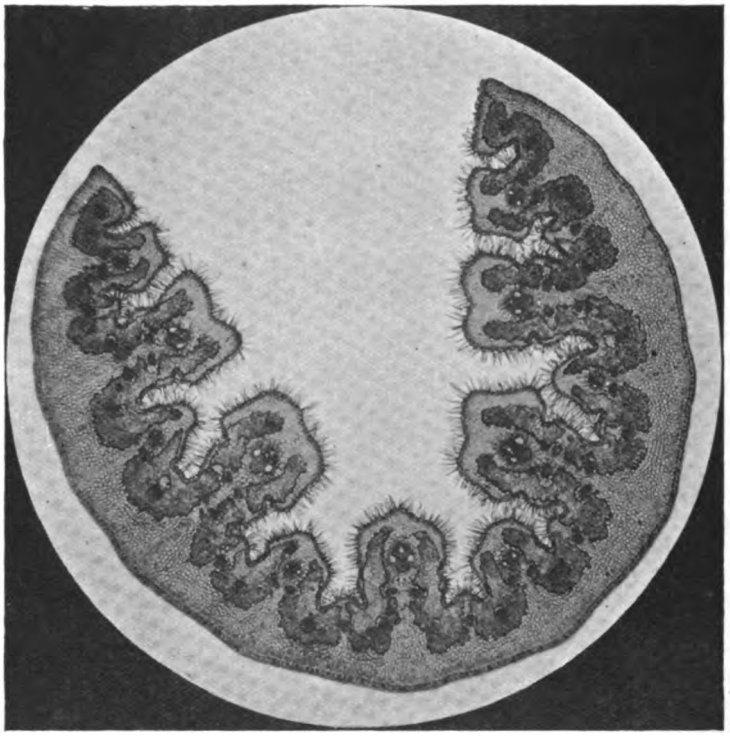
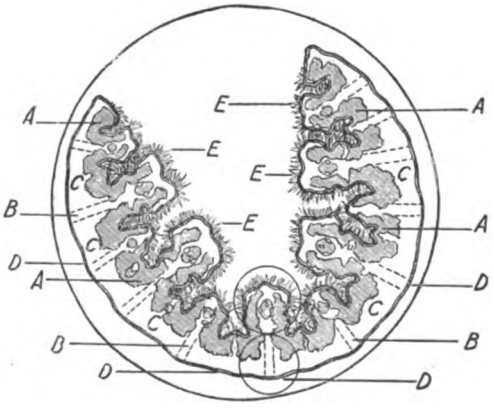


FIG. 4.—SECTION OF ESPARTO LEAF, MAGNIFIED 52 DIAMETERS.



KEY TO FIG. 4.

A.—Fibro-vascular bundles.
B.—Bundles of lignified fibres.
C.—Smaller fibres.
D.—Cuticular tissue.
E.—Seed hairs.

(The circles show the areas under magnification of 325 diameters, illustrated Figs. 5 and 6.)

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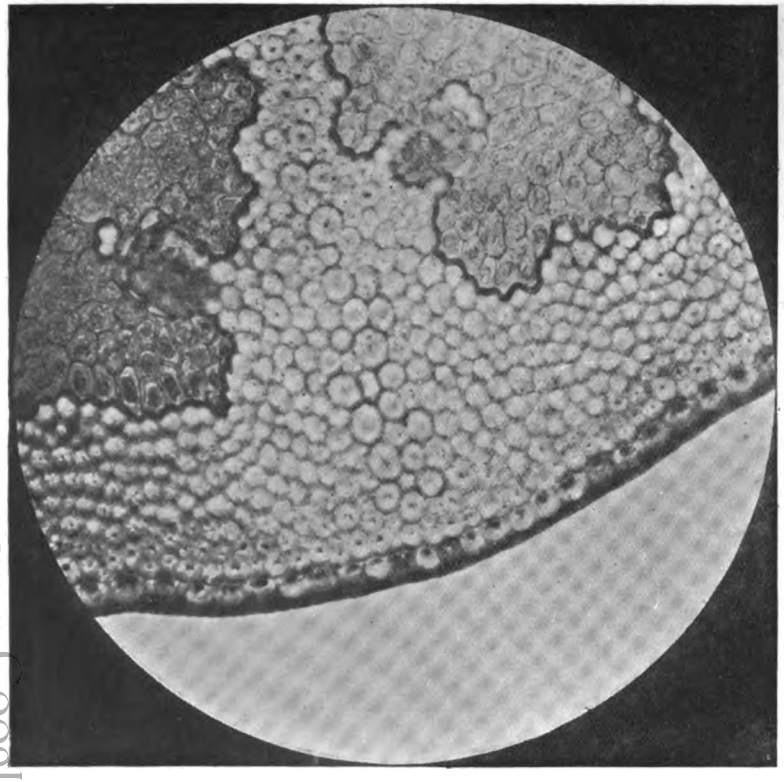

FIG. 6.—SECTION OF ESPARTO LEAF, SHOWING CUTICLE, LIGNIFIED FIBRES, FIBRO-VASCULAR BUNDLES AND SMALLER FIBRES, ETC.
Region as shown in lower circle of key to Fig. 4.
(*Magnified* 325 *diameters*).

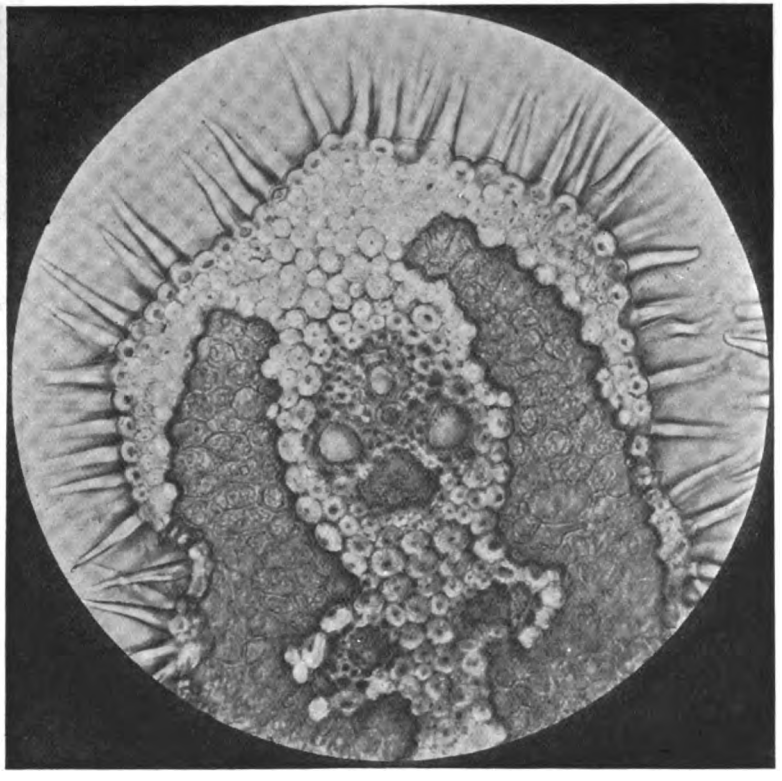

FIG. 5.—SECTION OF ESPARTO LEAF, SHOWING SEED-HAIRS AND FIBRO-VASCULAR BUNDLES, ETC.
Region as shown in higher circle of key to Fig. 4.
(*Magnified* 325 *diameters*).

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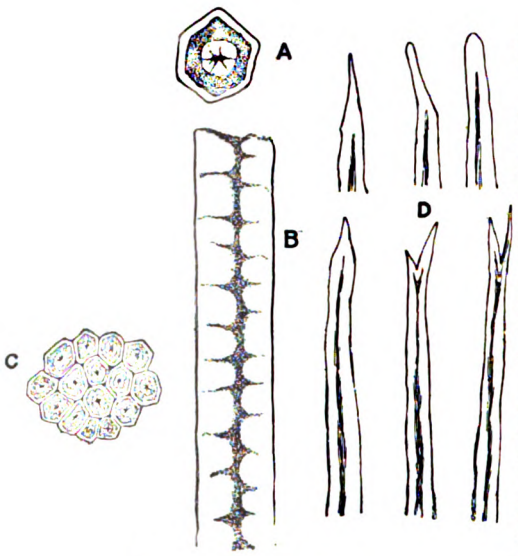

FIG. 7.—ESPARTO FIBRES.

A and B.—Transverse and longitudinal sections of the Esparto Fibre as seen under very high magnification, showing secondary thickening of cell walls and spiral radiations of central cavity.

C.—Bundle of Fibres under lower magnification.

D.—Fibre ends.

The best grade Esparto (Spanish) yields about 45 per cent. of paper-making fibre; Tripoli grade about 41 per cent.

Chemically speaking, the pure bleached isolated fibre is not normal cellulose ($C_6 H_{10} O_5$), but an oxy-cellulose, resembling very closely, in the percentages of carbon, hydrogen and oxygen, the cellulose of bleached straw pulp. This class of oxy-cellulose gives a characteristic rose-red coloration when boiled with aniline sulphate. This reaction serves in some measure as a rough means of determining the proportion of Esparto or straw fibres in commercial papers.

Esparto cellulose (*i.e.* bleached fibre), resembles straw cellulose in that it yields large quantities of *furfural* by solution and hydrolysis with H C l. Oat straw cellulose yields 12·5: Esparto cellulose, 12·2. Esparto cellulose furthermore reacts with Fehling solution, Phenyl-hydrazine salts, and magenta-sulphurous acid. To these reagents normal cellulose, such as cotton, is inactive. Cases have been noted of Esparto papers developing a magenta coloration after storing for years, due probably to the presence of aniline salts.

On mounting a fine-cut section of the dried Esparto leaf under the microscope, and treat-

mill is about 85 per cent. The "causticity" of the recovered liquor is from 93 to 95 per cent. To arrive, therefore, at the actual consumption of soda per boiling or per ton of grass, one has to take 15 per cent. of the amount actually used, since 85 per cent. is recovered and used again: the loss being made good by the addition of fresh caustic soda.

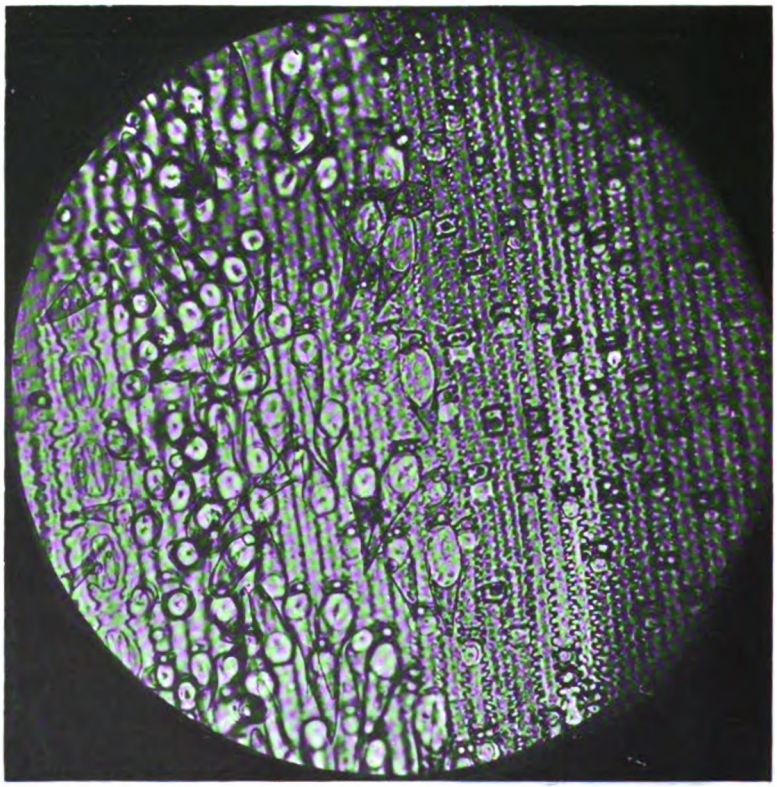

FIG. 8.—SURFACE VIEW OF CUTICLE OF ESPARTO, SHOWING STOMATA, SEED-HAIRS, SERRATED CELLS, ETC.

(*Magnified 325 diameters*).

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ing with alcoholic fuchsine, it will be noticed that the rows of fibres immediately under the epidermis remain colourless, and also a band of fibres radiating from the epidermis to the fibro-vascular bundles and surrounding them. The other fibres will be slowly coloured red. By treating another section with iodine and potassium iodide, and then with sulphuric acid, the fibres affected by fuchsine become coloured a blue tint, whilst the litrified fibres turn yellow, more particularly on their external edges. By means of such reagents the different kinds of fibres in the section of the leaf can be readily distinguished.

In the case of hemp, wood, flax, cotton, and such fibres, a large amount of mechanical energy has to be expended in subdividing them for paper pulp, which treatment is unnecessary in the case of Esparto, in consequence of the convenient length of its fibres. The fibre of particular use to the paper-maker is derived from the fibro-vascular bundles and other lignified regions (see Figs. 4, 5, 6, and 7), and is polygonal in section, frequently approximating to a hexagon. The hexagon is frequently formed in nature as the result of

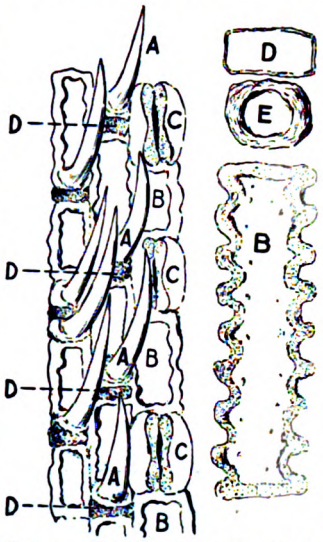

FIG. 9.—THE COMPONENT PARTS OF THE CUTICLE OF THE ESPARTO LEAF.

A.—Seed-hair.
B.—Serrated cells.
C.—Stomata.
D.—Oblong thin-walled cells.
E.—Circular thick-walled cells.

(*The cells on the right are represented under much higher magnification.*)

lateral pressure due to growth and expansion: it can be artificially produced by pressing together a number of round rods made of lead. Without pressure, Esparto fibre would probably be cylindrical.

The cell walls show secondary thickening and a very small central canal. The fibres are slim and smooth, the ends generally tapering, but sometimes branched (see Fig. 7). This ultimate Esparto fibre, when isolated by chemical means, measures from 3·5 mm. as a maximum, to 0·5 mm. as a minimum in length. The large majority in Algerian grass are about 1·5 mm., with a diameter of 10 μ. The ratio of length to diameter is then $1500/10 = 150$. The ancients, and those who have followed their example up to the present time, made use of the whole of the dried leaf of a thickness of from 1 to 2 mm.,

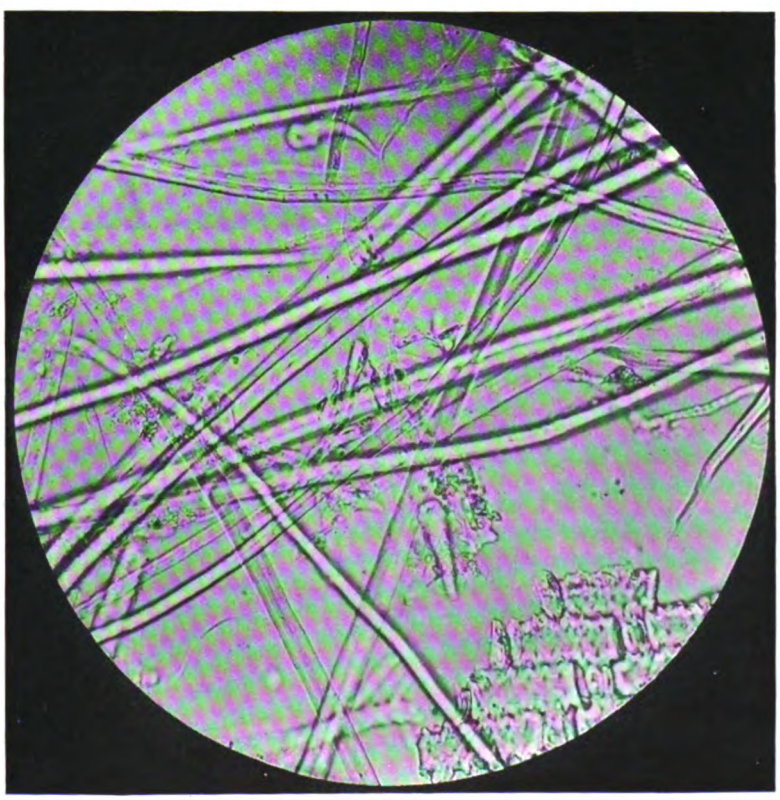

FIG. 10.—ESPARTO PULP, SHOWING LONG PAPER-MAKING FIBRES, TWO CHARACTERISTIC SEED-HAIRS, AND THE SERRATED AND OTHER CELLS OF THE EPIDERMIS.

(*Magnified* 325 *diameters*.)

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for the purposes of weaving their goods, whereas the paper-maker of to-day makes use of the ultimate fibre after its separation by an elaborate process of chemical treatment. The time-honoured method of weaving Esparto involved the use of units consisting of many, many thousands of ultimate fibres aggregated together, the strength and general usefulness depending chiefly on the cementing and encrusting materials, holding the minute fibres together. The paper-makers' fibre is, therefore, a very small atom as compared with the dried leaf. In addition to these long-shaped fibres, one almost always finds in Esparto pulp the serrated cells and seed-hairs of the cuticle, which survive the chemical treatment and find their way into the finished pulp. Unless, however, the washing of the pulp is most carefully conducted to free it from bleach-liquor, etc., a large proportion of the fine seed-hairs, resembling sharp teeth, together with many of the serrated cells of the Esparto cuticle, find their way through the wire meshes of the washing drums and are lost to the paper-maker. The serrated cells are often much distended in width by the chemical treatment to which they are submitted (compare Figs. 8 and 10 under equal magnifications).

All papers have a tendency to expand and contract with changes in the humidity of the atmosphere. This often presents serious difficulties to the printer, more particularly in colour printing, where any change in the size of the paper would throw his work out of register. Practically all papers expand; but machine-made papers, in particular, expand unequally in the different directions. It has previously only been surmised that this has to do with the micro-structure of the paper. Papers which are much stronger in the machine direction often show great difference in expansion of the two ways of the sheet, when wetted on one side only. The so-called "machine direction" of a sheet of paper can readily be determined by cutting out a disc $2\frac{1}{2}$ inches in diameter, quickly wetting the whole of one surface, and holding the disc up with a pair of forceps. The edges of the disc will curl with the wetted side outermost, the edges often meeting to form a cylinder. The axis of the cylinder indicates the machine direction. The probable reason is, that most of the fibres lie in the machine direction; and, when wetted, expand in a greater ratio in diameter than in length. The greater strength of machine-made paper in the machine direction is due to the fibres mostly lying along that direction. The direction of the fibres has, up to the present, been assumed from the physical properties and the "tear" of the paper, and we think that the photo-micrograph here shown (Fig. 11) affords

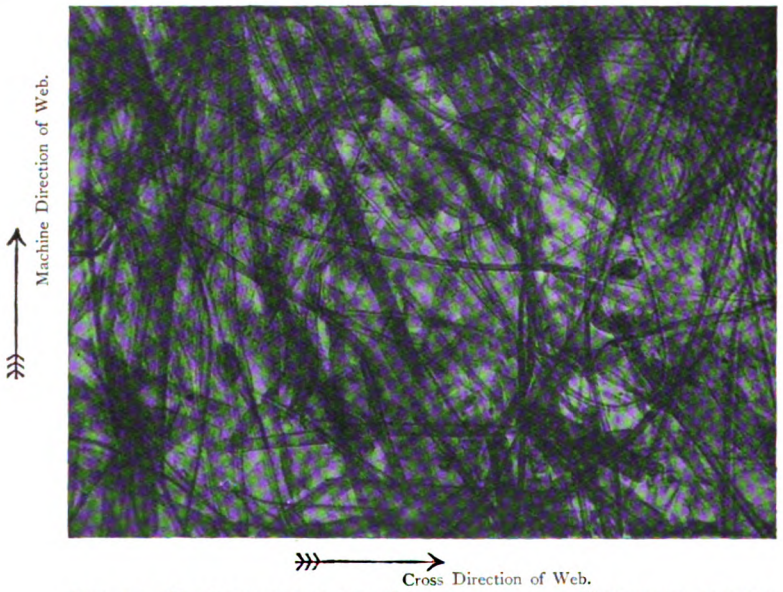

FIG. 11.—TO ILLUSTRATE THE DISTRIBUTION OF FIBRES IN TYPICAL MACHINE-MADE ESPARTO PAPER.
(Photographed from thin section split parallel with surface of paper.)

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the first proof that the assumed direction does exist.

The following table gives the "lie" of fibres, assuming that the angle of the "machine" direction is zero. The fibres are taken from left to right along an imaginary line across the centre of the photo-micrograph (Fig. 11.)

Fibre.	To Right of Machine Direction.	To Left of Machine Direction.
1	35°	—
2	—	17°
3	3°	—
4	—	6°
5	15°	—
6	4°	—
7	10°	—
8	—	10°
9	—	5°
10	—	5°
11	1°	—
12	4°	—
13	6°	—
14	—	*60°
15	—	*46°
16	—	30°
17	—	*87°
18	—	33°
19	25°	—
20	—	43°
21	—	*47°
22	—	28°
23	5°	—
24	2°	—
25	—	2°
26	15°	—
27	—	*70°
28	—	*85°
29	15°	—
30	5°	—
31	—	10°
32	*65°	—
Mean . .	14°	33°

Composition of Fibres of Foregoing Paper.

Percentage by weight of fibrous constituents:—

Esparto	about 80
Chemical wood . .	„ 20
Hygroscopic moisture of paper when tested	8·74%
Mineral matter contained in paper .	19·28%

* Only seven fibres inclined at a greater angle than 45° to the "machine" direction, whereas in an ideal paper equal in strength in both directions there would be half the fibres, or 16 out of the 32 measured.

An ideal paper should have fibres disposed equally in all directions to assure uniformity in strength and felting qualities. This would give a mean angle of 45° on either side of zero, whereas in the above paper the mean angle of fibres is only 23·5°. This accounts for the much greater strength in the "machine" direction of the web.

Physical Constants of Paper.

Grams per cubic centimeter: –

Total	0·85
Fibre	0·686
Mineral	0·164

Percentage by volume:—

Fibre	45·7 per cent.
Mineral	6·6 „ „
Air space	47·7 „ „
	100·0

Breaking strain expressed in lbs. on strip 1 in. wide and 2 in. between clips:—

A. When pulled *across* "machine" direction.	B. When pulled *along* "machine" direction.
4·2 lb.	12·5 lb.
3·8 „	11·8 „
3·0 „	13·5 „
3· 5„	11·7 „
3· 5„	13·5 „
Mean 3·6 „	12·6 „

Mean of both directions (A and B). 8·1 lb.

Ratio of "cross" to "machine" direction, 3·6 : 12·6 : : 1 : 3·5.

Mean breaking strain for two directions, in grams on strip 25 mm. wide = 3669.

Thickness of paper = 0·048 mm.

Sectional area of strip broken, 2·10 sq. mm.

Strength of paper expressed in grs. per sq. mm. of sectional area.

	Grms.
Cross direction	777
Machine direction.	2718
Mean of cross and machine direction	1747

"Bulk" expressed on ratio of fibre volume to total volume (when fibre-volume = 1) 2·19

In a first-class Esparto paper, strength is not of primary importance: as a rule, sufficient strength can be secured by the addition of about 20 per cent. chemical wood pulp. "Bulk" is of greater importance. More than half the thickness of an Esparto paper is due to air spaces. Very little of the bulk is due to the empty space of the central canal of the fibre itself. With many paper-making fibres, the central canals are comparatively large, and the "bulking" due to the central canals considerable. Although the ultimate fibre of the Esparto is almost solid, having an "Apparent Specific Gravity" approaching 1·50, yet when felted, the fibres form a paper having an Apparent Specific Gravity not greater than 0·686. The inference is, that Esparto fibre possesses very great bulking quality. When mineral is added, as in the above-mentioned case, it occupies spaces between the fibres, and

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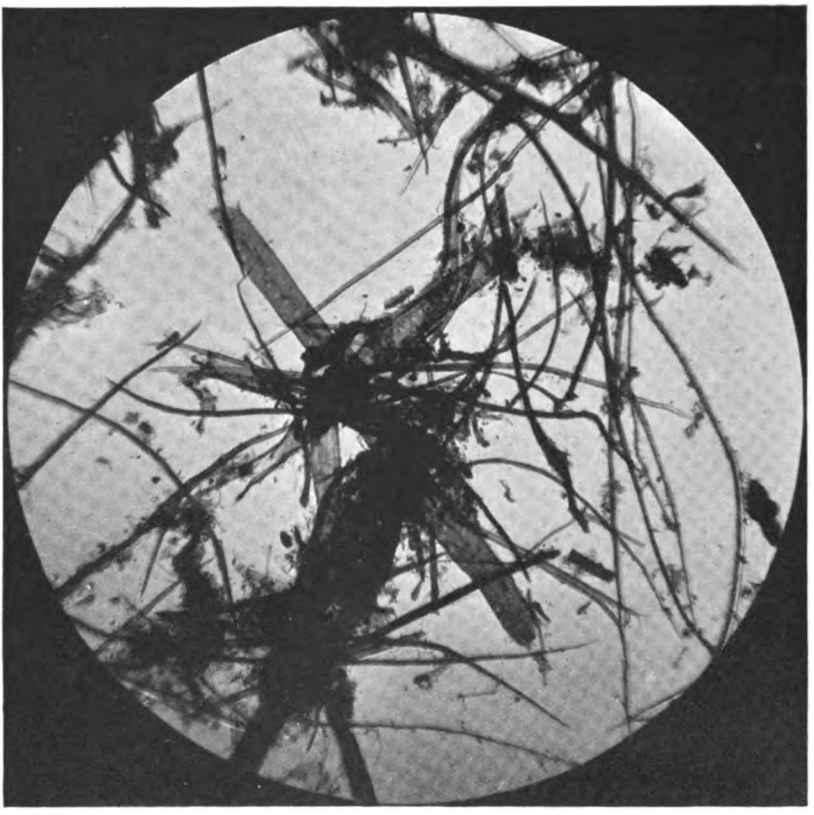
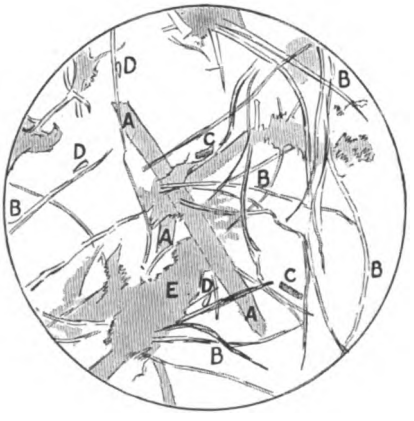


FIG. 12.--FIBROUS CONSTITUENTS OF THE PAPER UPON WHICH "TECHNICS" IS PRINTED.
Magnified 90 diameters.

tends to fill up the interstices. In other words, it adds to the weight without increasing the bulk.

Esparto yields one of the shortest as well as one of the thinnest in diameter of paper-making fibres. Being short, it has not the power of giving great strength to paper; but there is a soft, smooth suppleness in the fibre which endows it with special characteristics not possessed by any other. Its introduction to this country has given us pre-eminence in the illustrations of the best journals and periodicals, which other countries are not able to imitate except by means of thickly-coated and highly-glazed art papers, which are fatiguing to the eye.



KEY TO FIG. 12.
A. Chemical wood fibres.
B. Esparto fibres proper.
C. Serrated cells of Esparto.
D. Esparto seed-hairs.
E. Regions containing size, coating material, and broken fibres.

Taking the case of Canada, in recent years English paper has to a large extent been superseded by paper made in the United States; but British Esparto papers still hold their own, as the Yankee so far has not been able to find a substitute.

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SIDE LIGHTS ON TECHNICAL EDUCATION IN AMERICA.

By JOHN HULME.

WERE one seeking a phrase that has, more persistently than another, loomed across the public vision during the last twenty years, it would be found in the words "technical education." There are few who have not bestowed upon it some thought, whilst many have ventured so far as giving it a definition. Without going into the pros and cons of these definitions, we might clear the ground a little by saying that art is the use of means to an end: science, systematized knowledge; and technical education, learning how to apply science to art.

Now, as scarce a week passes without some public reference to the loss of our trade, the question naturally arises, "What is the loss due to?" Various reasons are given, one of them being the superior skill of the American workman, owing to better technical education. I myself must confess that I have, as yet, been unable to detect this superiority. I have never even found anyone else who could prove it to me, either here or in the United States. It is very easy to spin sentences, and the phrase "superior technical education" falls trippingly from the tongue. The sentence, however, has been so frequently used as to have become somewhat of an obsession, so that one can scarcely allude to our industrial barometer without hearing (like King Charles' head in Mr. Dick's case) this overworked expression dragged into the conversation.

Eventually we are tempted to exclaim, "Well, supposing that the American has applied his systematised knowledge to the end of turning out more, better, and cheaper textiles, boots, and machinery than we, it would certainly pay us to investigate his technological method, for the purpose of adopting it, should our examination prove satisfactory."

But we can only do this by mixing with our kinsmen workers across the Atlantic, and living their life in every mood and tense of the verb. This means spending a longer time among them than is usually possible with the average visitor to the United States. Nothing short of this, however, will serve. America is a young country, and the American has all a youth's enthusiasm and tendency to exaggeration: superlatives play a large part in his speech. With him, it is always a case of "either Cæsar or nobody," and he has a slight tendency to view his own work through a magnifying glass. Hence it is not quite safe to rely upon opinions conveyed in language at times faintly reminiscent of the Arabian Nights. It may seem a trifle ungracious not to accept his word unquestioningly, but accuracy demands that we should test every statement—this without any disrespect whatever. He, no doubt, honestly believes himself to be, educationally speaking, all he claims to be. But it has been conclusively proved that, to say the least, the American boy or girl at fifteen years of age is no better educated than a pupil of the same age in our own schools. Suppose, then, that we follow their respective careers until they are twenty-one. By confining our attention to those intending to pursue one or other of three staple trades, say, textiles, iron, and boots, it will be much easier to get trustworthy and useful information than by fruitlessly endeavouring to deal with a greater number of trades all over the country, and ending by hearing nothing but a number of eloquently worded syllabus descriptions of buildings, staff, and endowments.

Our task is, therefore, a simple one. We have merely to trace the progress of three youths in Oldham, Sheffield, and Northampton on the one hand, and Lowell, Pittsburg, and Haverhill on the other. In Great Britain the training of a workman has always been like that adopted by the old masters and their artist pupils. The latter learnt their art by imitation of, and practice side by side with the former. "Perfection only comes by repetition," was their motto. The results achieved by them have not been excelled. In like manner, the Lancashire textile operative has never swerved from his position that the most effective of all training is that received in the "jenny gate," or "weaving alley," under the guidance of skilled journeymen and journeywomen. The technological institute, to these people, is always kept in a subordinate position to assist, not to

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replace. Hence, during the day, the Oldham youth is acquiring digital dexterity. At half-past five or six o'clock he quits work; and, after tea, puts in two or three hours at the local technical school. The conditions of his work and the nature of the British climate enable him to do this without experiencing unusual fatigue. In this way it is possible to spend eighteen hours a week in the lecture rooms and laboratories. Twelve hours so spent is quite a customary experience. It will thus be seen that, taking an average case, he passes nine hours a day with practical experts in the works, and two hours every evening with another set of experts who are teaching, or ready to teach him, the scientific principles underlying everything he has done during the daytime. After five years spent in this manner the studious apprentice is nineteen years of age, earning about 16*s.* to 18*s.* per week, and ready for his first promotion—"joining at spinning." He is now an ideal workman. He has a useful knowledge of mathematics, is acquainted with elementary physics, and well up in his own art. Turn him out in whatever part of the world you will, he comes first—not among the first, but first—in his trade; and employers will always bid for his services as a textile worker—aye, even in Germany, where they don't give the Briton more than he is entitled to. A process of natural selection from these spinners supplies the foremen, whilst a similar process furnishes the manager.

The youth leaving a Sheffield board-school may choose the iron and steel industry, in which case his well-planned evening studies will be chiefly chemical and metallurgical, with, of course, elementary mathematics and physics. In Northampton, also, similar provision exists for supplementing the day's work of the shoemaking apprentice.

It is necessary thus to glance at how English artisans are trained, in order to note the difference and superiority, or otherwise, in the American system.

Let us now turn to Lowell, a typical textile manufacturing town. Here we find the son of poor parents, instead of going to work at fourteen, may wish to continue his education. His parents thereupon send him to the high school, where he receives four years' additional free tuition. At the end of this time he has still his trade to learn, though we are told that with the knowledge he has obtained he will readily make up leeway and outstrip, say, the Oldhamer as a cotton spinner, or the Sheffielder or Northamptonian as a cutler or shoemaker.

But we are confronted with the fact that these latter, in addition to nine hours a day at their respective trades, have been putting in two hours per evening at pure and applied science. Therefore, if the Lowell youth's knowledge is greater than theirs, we expect to find it a little above the ordinary. This is not the case, for the total of the chemistry and physics he has acquired would not enable him to more than pass the elementary science examinations conducted by the Board of Education in this country. And it must not be forgotten that, on the scientific side of a high school in the States, the pupil is supposed to be specially prepared for the technical school, leading to subsequent work in a cotton or other mill. There is, therefore, an appropriate spot at which to pause in order to anticipate a possible question regarding the extent of the science teaching in an American high school.

From the attractive manner in which the syllabuses are drawn up, I myself was under the impression that the courses there would be at least equal to the advanced stages (Board of Education, Great Britain). Still, I wanted to see for myself, and hence always endeavoured to secure, and nearly always succeeded in obtaining, a set of the exercises worked by the students during their four years course. It is the only way of getting at the facts. A typical collection of one of these sets of exercises I have placed in the hands of the editor of "Technics," who will know how to appraise them. Looking through them, one finds that there are just forty experiments all told, in mechanics, magnetism, and electricity, and sound, light, and heat. From this it will be gathered that there are not many hours allotted to each subject, and one need not be very uncharitable to assert that it does not betoken the imparting of any profound acquaintance with physics, certainly nothing to justify the eulogiums so frequently passed on the superior mental equipment of the American student at this stage of his career. It is necessary to harp upon this string, in order to emphasise a point that is nearly always lost sight of, namely, *that the British lad begins his technical education four years earlier than the American*, and that the only time to make a comparison between them is when they are both nineteen, at which age it will be found that the studious British iron smelter, engine fitter, textile worker, or shoe hand is the better equipped mentally, and is an expert artisan in the bargain. "But," says the thoughtful Yankee, "wait until I

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have put in an additional four years at school, and then you'll find I am an embryo foreman or manager, whereas your Lancashire, Yorkshire, or Northants youth will rarely become anything but an ordinary workman."

Here, again, we meet with the great distinguishing idea of the two countries. The Briton says, Let us have skilled workmen; we shall then never want for skilled foremen and managers. The American, on the other hand, chiefly regards technical education as a means of supplying supervision for less efficient labour. At any rate, in the hope of becoming a foreman or manager, the Massachusetts youth will, at the age of nineteen, proceed to, say, the textile school for a four years course. Here he will maybe study machine drawing, textile machinery, and fibre manipulation, together with machine calculations. Or, if he is intended for the dyehouse or calico-printing shop, he goes through a number of experiments on small (5-gram) pieces of cloth, showing the action of discharges, mordants, artificial colours (direct and basic), natural colours, a little water analysis, and a few dye trials. After a very careful investigation of the work done in the dyeing department of one of the best textile schools in the United States, I found that there was not one of the fourth year's students who would not have all his string extended in passing the honours examination held by the City Guilds of London; and yet we know that these successes are gained readily enough every year by our own students, who work at the "jigger" or in the "bleachcroft" during the daytime, and get their theory after half-past five at night.

The American textile student, then, has remained until he is past his majority at the high school and the technological institute, and yet is no better qualified, scientifically, to be either foreman or manager than is his British relative, whilst as a practical man the latter is miles ahead. I was so impressed with this aspect of the case that I asked the manager of one of the largest textile mills in America what use he would have for one of his countrymen who had been trained in the way I have above indicated. His reply was: "As an ordinary workman, he would still have the bulk of his trade to learn. He would always go under when industrially opposing a studious young calico-printer or 'minder' from the old country; and the latter would, in time, be almost sure to gain a supervisional post, especially if he happened to take out his naturalisation papers. Where we differ from Great Britain is in allowing pupils to spend their vacations in our mills, and paying them a living wage as well, whilst they are doing so. But, even then, our students never get the practice yours get; and, strange to say, their science after all seems to be no better than that of the British evening student. There is no doubt that much time is wasted at our American technical schools in going through courses fixed by people who call themselves organisers. One half the subjects in these courses are quite useless, and it is almost necessary to have a special education in order to understand our elaborately drawn up syllabuses."

This experience coincided, by the way, with that which I had received at Haverhill, a few weeks earlier, and which I shall describe directly.

If we insist upon judging a system by its results, then a visit at this very time to the Manchester Institute of Technology, for the purpose of inspecting the specimens of work done by sanitary engineering students, and sent over here for exhibition by American technical school authorities, is instructive; and makes one feel an undoubted pride in the British artisan, in spite of the reproof we are continually giving him and the praise we are so readily inclined to bestow on those on the other side of the big silver streak.

It sounds wonderful to hear that there are 1400 students at the Massachusetts Institute of Technology. But this number is small by the side of the 6000 evening students in attendance at the Manchester Technical School, to say nothing of the 3000 at the Salford Institute (only two miles distant), and numbers approximating to these at Wigan, Oldham, Bolton, Ashton, and Stockport—towns within a ten-mile radius of Cottonopolis. Then, again, London may have been late in moving in this matter, but where, now, in New York or Chicago is there a collection of technical colleges to equal those at Finsbury, the Central, the East London Technical College, etc., in the metropolis.

Whether the comparison is made with regard to attendance, curriculum, or research, we need not feel ashamed. With regard to the quality of the teachers in an English secondary school, it must not be lost sight of that politics plays no part in their appointment.

When in the United States I have, on different occasions and for observational purposes, asked permission to go into some textile or other mill, and work as a common

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or garden hand; and to my surprise often found that the majority of superior posts in such concerns were filled by Britons. The inference is obvious. Our system of technological training, judging by its fruits, cannot be inferior to the American one. It is also suggestive to learn that last autumn, at a convention of engineers held in one of the large cities of Pennsylvania, figures were given showing that three out of every four of the superior situations in the American engineering trade were held by foreign-born residents. When one, therefore, hears of the posts waiting for graduates from American technical colleges, the feeling will force itself forward that the calibre of the native workman has been vastly overrated, seeing that he is, apparently, rarely fit to be promoted.

One day, whilst on a visit to my friend Mr. Moody, Secretary of State for the U.S. Navy, I encountered on the Haverhill car a Mr. Barlow, assistant superintendent of the Pacific Mills print-works. "You are quite mistaken," said he, in answer to one of my remarks, "I did not continue my studies in this town after arriving from England, for the simple reason that there was no institute at which I could obtain advanced instruction in chemistry of an evening; and the knowledge of science I had gained as an average-day student at the Central Schools, Manchester, was far greater than anything I could obtain here."

"But what about the men who are trained in the technical colleges, as distinct from your evening pupils?"

"It would be a shame if, at 22 or 23 years of age, they were not better educated than those who only attend evening classes; but even in that case the standard of attainments is much below what we might expect. It, at any rate, seems so when compared with what we used to do at home, where, the year I left, we gained no less than ten honours in inorganic and organic chemistry. This by lads of fifteen; and it was thought nothing extraordinary as a feat deserving extra eulogy. Why, that is all these men are able to do after spending eight years at science. The students, here, appear to learn too much about everything in general, and not enough about one thing in particular—the main one—that which immediately bears upon their own art."

Mr. Maguire, proprietor of a large boot manufactory at Haverhill, said, in reply to one of my questions as we were inspecting his works: "It is nonsense talking about the success of the American boot trade being greater than the British, and due to superior technical education and improved machinery. It is simply due to energetic booming and an ever-increasing market that is preserved for us. So far as education goes, I want you to note that this town of Haverhill is the third largest shoemaking centre in the States, and yet we have not a single technological class. Furthermore, there is not a machine in my works that cannot be found in Leicester or Northampton, whilst the operatives we get from the old country are unexcelled by any in the trade."

Let me supplement this testimony by remarking that on August 24, last year, I was a guest of the Associated Boards of Trade of the Merrimack Valley, at their annual banquet, and had thus an unusual opportunity of rubbing shoulders with the leaders of industry in all the large cities situated in the vicinity of that historic river. But no matter with whom I conversed, or what the trade we discussed, the verdict tendered to me was that we in Great Britain have reason to be satisfied with our workmen. If this is so, then it speaks well for the system under which those workmen are trained, and, inferentially, tells a little against the practice in vogue in the United States.

In all fairness, however, it must be borne in mind that Uncle Sam has not the same supply of skilled labour that John Bull has; and, therefore, has to economise, often by putting it in charge of unskilled workers. The rapid internal development of the country creates a continual demand for trained help, which the various technological colleges are called upon to assist in supplying. Were the men who have been trained at these institutions even better qualified than they are, on completing their studies they would find a difficulty in obtaining employment in Great Britain, owing to competition with a greater supply of skilled labour. An example may be useful here: During a conversation with the President of the Massachusetts Institute of Technology, and after mentioning the case of a young Cheshire ironworker who had, last May, gained a couple of successes in organic chemistry, double honours in inorganic chemistry, besides double honours in metallurgy, I wished to know the prospect for him in the United States. "He would, in Pennsylvania, be a foreman at thirty dollars a week, in less than six months," was the reply.

Well, this artisan is actually at present walking about among the Cheshire unemployed. Yet no one could accuse the London & North-Western Railway Company of being other than an up-to-date firm. They

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have no fault to find with the workman in question. But they are temporarily reducing their staff, and as their supply of equally efficient artisans is plentiful, this particular one's undoubted talent cannot be made use of. I have other similar cases in view as I write, and the reflection will intrude itself that, were they to respond to offers held out to them on the other side of the Atlantic, they would subsequently be pointed out as fruits of the American system of technical education.

Two years ago, whilst enjoying the hospitality of Professor Mendeleef at St. Petersburg, our conversation drifted to the States, and then to the Massachusetts Institute of Technology. In answer to a question from my host, I replied that I had never had an opportunity of seeing the much spoken-of institute, but was anticipating the treat. Last autumn my longing was gratified, and, frankly, I could not put my feelings exactly into words. On leaving the institute I had still a high opinion of it, but it no longer represented the last word on technical education. There is no denying that it is a magnificent building, splendidly equipped and staffed. And yet I have no hesitation in saying that, had we the same college in Great Britain, we could turn out better results with it. By such an expression I do not mean to say that we have not a technical college in England equal to it. As a matter of fact, the Manchester School of Technology equals it at any point, and excels it in several —such, for instance, as in the departments devoted to textiles, and dyeing, and calico-printing. By the appointment of a staff of qualified and salaried research assistants the authorities of the American institute have, however, not only gone ahead of us, but have earned the thanks of all scientists. The bulk of its students come from the high schools, where, during the whole of their time, they have been preparing for the institute's entrance examination, the passing of which they are allowed to accomplish in sections—a feat which cannot be held as a great proof of intellectual superiority. To test the matter I recently had these entrance examination papers set, at a few minutes' notice, for the boys and girls (aged 15) in the upper form at two different higher grade board schools, and in no instance was there a failure.

It would be a needless task to minutely mention the programme in every department of this, the principal technical college in the States. But, by examining the work done in one we obtain a pretty fair idea of the work turned out in all. To become a chemist, I find that during my first year at the institute I must take classes in military science, rhetoric, freehand drawing, United States history, wood- and metal-work, French, mechanical drawing, algebra, geometry, trigonometry, theoretical inorganic chemistry (two hours a week), and practical chemistry (four hours a week).

In my second year I study European history, English literature, French, physics, mineralogy, theoretical inorganic chemistry, qualitative analysis, and the quantitative determination of Fe, Ca, Mg, HCl, H_2SO_4, H_3PO_4, and H_2CO_3.

In the third year I take political economy, history, law, physics, quantitative analysis of silicates and minerals, and receive ten lectures in elementary organic chemistry. In my last year I learn gas analysis, oil testing, receive sixty lectures on organic chemistry, do twenty organic preparations, attend some special optional class, and write out a report or thesis. I am now twenty-three years of age, and have an amount of knowledge sufficient to enable me, were I in England, to pass Honours Part I. (Board of Education.)

"Our system," said the chief of the institute, when discussing this subject with me last October, "is different from yours in Great Britain. You only turn out workmen; we, supervisors."

Well, I have, in imagination, just now gone through the system, and, of course, must be qualified for a post as foreman, or assistant manager, in an American works.

Such a qualification, however, would certainly not get me an assistant-managerial post in Lancashire. And I could not resist, good-naturedly, calling President Pritchett's attention to the fact that, only a few months previously, our workmen students, as he termed them, were expected by their examiners to, in eight hours, do a gravimetric determination of silica as well as a gravimetric and volumetric estimation of iron in a specimen of grey pig. It is true they had learnt no military science, law, and history, but they proved themselves to be sound chemists. Before me, as I write, lies the four years' work in one section of science, done by the picked student of a prominent high school in New England, by virtue of which he was given a post in a governmental establishment. He would have needed a much better record to secure a less valuable berth in Old England. Comment is needless. I have given the bare facts—adding nothing, selecting nothing, rejecting nothing.

"We can get stacks of money for education," said Mr. Horne, principal of the Law-

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rence High School. This was the story, too, of my friend Professor Hersom, of the California University. So they can. Their buildings and equipment leave little cause for complaint. What money can do has been well done, but it cannot remove the necessity to work if knowledge is desired. And the Americans do not appear to turn out as much work in the same time as we. Neither does there seem to be as great a quantity of high-class work as in Great Britain.

Johns Hopkins University, however, is a noble exception. If there were a score of such institutions in the United States, then one might feel inclined to award our transatlantic relatives that which they now assume without meriting it—the credit of being foremost in general as well as technical education.

PIN-HOLE PHOTOGRAPHY.

By EDGAR SENIOR.

IT is well known that if the lens be removed from a camera and a diaphragm with a pin-hole orifice be substituted in its place, a remarkably good photograph can be obtained. Such photographs possess advantages over those obtained by the aid of a lens, in so far as distortion is entirely absent, and the artistic effect obtained is extremely pleasing.

It is generally urged against this process that an excessively long exposure is required. The accompanying photograph was obtained at Bonchurch, Isle of Wight, in August 1903, using a small aperture of $\frac{1}{80}$ inch diameter, with an exposure of two minutes.

It is well known that for a given aperture an image will be obtained whatever may be the distance from it to the plate; but it was proved many years ago by Lord Rayleigh, as a consequence of the Wave Theory of Light, that the best definition is obtained when the diameter D of the aperture is related to the distance L from it to the plate, as given by the equation

$$D = 2\sqrt{\lambda L}$$

where λ is the wave length of the light employed.

Taking account of the wave length of the light employed in photography, Sir William Abney gives the formula

$$D = \frac{1}{120}\sqrt{L}$$

where D and L are measured in inches.

It was proved by Lord Rayleigh that when the conditions specified by his formula are complied with, no improvement could be obtained by using a lens of the same aperture as the pin-hole.

PIN-HOLE PHOTO BY EDGAR SENIOR.

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THE CONTINUOUS-CURRENT DYNAMO.

PART V.

By H. M. HOBART, M.I.E.E.

IN present practice, voltages above 650 are seldom used in the continuous-current dynamo. It is probable that 1000 volts, and even higher, will soon be freely employed; but it is not probable that slot insulations more than 50 per cent. thicker than for 500-volt practice will be used. Thus, somewhat less than 2 mm. will be allowed for slot lining. This will be practicable through greater care in the choice of material. At present, several tough materials of high disruptive strength, possessing good properties in other respects, are available; and improvement along these lines will, from present appearances, be comparatively rapid.

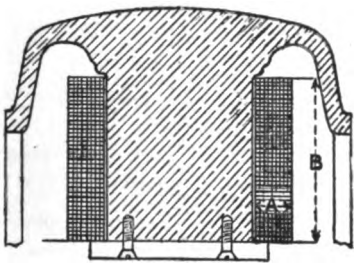

FIG. 45.

THE SPACE FACTOR OF THE FIELD SPOOL.

For field spools, the space factors are often far lower than is generally realised. As the winding space, we must take the product of over-all depth (A), by over-all length (B), of the completed spool, for spools of rectangular cross section. Such a spool is shown in Fig. 45. Where the cross section is not quite rectangular, as shown in Fig. 46, the *mean* length is multiplied by the depth in obtaining the winding space. If flanges are employed, the length between flanges is multiplied by the depth of the winding. Such a coil, wound within flanges, is shown in Fig. 47. Flanges have the disadvantage of retaining the heat.

The space factor of a field spool will be higher the lower the volts per spool; hence, for a given output, speed, and voltage, the greater the number of poles the higher will be the space factor, for there will be less volts per spool. For the shunt coils of continuous-current dynamos, the space factors generally range from 0·40 to 0·65, according to the speed, voltage, and number of poles of the machine.* In the series coils of compound-wound generators, the space factors are higher. The use of flat strip, wound on edge, generally conduces to a high space factor when the cross section required is such as to permit of the choice of a strip of favourable dimensions. Space factors of 0·7 and more may sometimes be obtained in the series coils of large, low-voltage, slow-speed machines, when edge-wound, copper strip is employed.

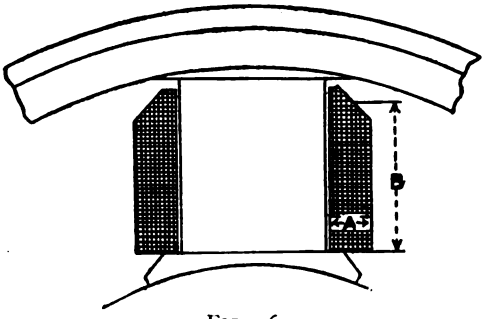

FIG. 46.

THE CALCULATION OF THE FIELD SPOOL WINDINGS.

The 400 k.w. dynamo, which has been taken as an illustrative example, requires the following magnetomotive forces per field spool for 550 terminal volts:—

Shunt coil (at all loads), 9,300 ampere-turns
Series coil (at full load), 4,420 „

In an 8-pole machine of this size and voltage, a space factor of 0·50 may be readily obtained, both for the shunt and series windings; and the available winding space may be divided roughly in

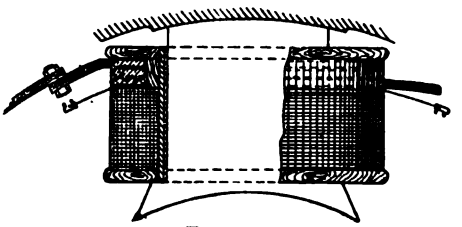

FIG. 47.

* In small continuous-current *motors*, space factors of less than 0. 25 are met with in 600-volt designs for high speeds.

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proportion to the respective ampere-turns required in the two coils. It is good practice to work the series coil at slightly higher intensity, since in the first place the losses therein are at their maximum only at full load, whereas the losses in the shunt coil are constant. Then again, the heat-dissipating capacity of a few turns of heavy copper conductor, is greater than for many independently insulated turns of comparatively small wire.

The winding space between end-flanges is, in this case, 40 centimeters. 28 centimeters at the upper end is employed for the shunt coil, and 12 centimeters at the lower end, for the series coil. The winding depth is 4 cms.

Calculation of the Shunt Coil.

An adjusting rheostat is used in series with the shunt coils. At full load, when the coils are at 60° C., less than 10 per cent. should preferably be wasted in the rheostat. This leaves 550 − 50 = 500 volts across the eight shunt spools, or 62·5 volts per spool.

Internal diameter of spool, cms.	46
Radial depth of winding, cms. (d)	4
External diameter of spool, cms.	54
Internal periphery of spool, cms.	145
External periphery of spool, cms.	170
Mean length of one shunt turn, in meters (a)	1·58
Ampere-turns per shunt spool (b)	9,300

Now there is a formula of great usefulness in calculating field spool windings. It is as follows:—

$$W = \frac{0{\cdot}000176 \times a^2b^2}{K}\ *$$

where

W = watts per shunt spool at 60° Cent.
a = mean length of one shunt turn, in meters.
b = ampere-turns per shunt spool.
K = kilograms copper per shunt spool.

This enables the calculation to be carried further as follows:—

$a\,b$	14,700
$0{\cdot}000176 \times a^2b^2$	37,800
Axial length of shunt spools, cms. (l)	28
Cross section of shunt spool winding, sq. cms. ($r = d \times l$)	112
"Space factor" of shunt spool (s)	0·50
Cross section copper in shunt spool, $t = r \times s$	56
Cubic centimeters copper in shunt spool ($100\,a\,t$)	8,900
Kilograms copper per shunt spool (1 cu. cm. copper = 0·0089 kgs.)	79
Watts per shunt spool $\left(\text{Watts} = \frac{0{\cdot}000176 \times a^2b^2}{\text{Weight in kgs.}}\right)$	480
External cylindrical surface per spool, sq. dm.	48
Watts per square decimeter of external cylindrical spool surface	10

This value will correspond to a thermometrically measured ultimate temperature rise of not more than 40° Cent. above the surrounding air.

The following steps relate to ascertaining the precise number of turns and size of wire, of which this 79 kilograms of copper per spool shall consist:—

Amperes per shunt spool = (watts ÷ volts per spool)	7·7
Turns per shunt spool = $\left(\frac{\text{ampere turns per spool}}{\text{amperes per spool}}\right)$	1,210
Cross section copper per turn, in sq. cms. = $\left(\frac{t}{\text{turns per spool}}\right)$	0·0462
Current density, in amperes per square centimeter	167
Diameter of bare copper conductor, mm.	2·42

Insulation employed on conductor, double cotton covering (D.C.C.).

Diameter of insulated copper conductor, mm.	2·65
Watts in all shunt spools at 60° C.	3,840
Watts in shunt rheostat at 60° C.	380
Total watts in shunt circuit at 60° C.	4,220
Weight of total shunt copper in kgs., all spools	630

Calculation of the Series Spool Winding.

The series winding is located in the 12 centimeters of space available at the lower end of the spool.

Of the 730 amperes of full load current of the machine, only 520 amperes are carried through the series winding. The remaining 210 amperes are carried through a "diverting" shunt in parallel with the series winding.

As 4,420 ampere-turns per series coil are required at full load, $\frac{4{,}420}{520} = 8{\cdot}5$ turns per spool must be provided. (It is often convenient to have an odd half turn, as it brings the terminals into convenient positions for interconnecting adjacent spools).

* The proof of this formula, expressed in British units, may be found on page 127 of "Electric Generators."

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The size of the series conductor is readily determined, now that the shunt winding has been calculated with so much detail. The shunt conductor is loaded to a current density of 167 amperes per square centimeter. It will be equally practicable to run the series conductor at a density of 180 amperes per square centimeter at full load. The conductor must thus have a total cross section of

$$\frac{520}{180} = 2.90 \text{ square centimeters.}$$

It may consist of a strip of copper, wound on edge. The strip may be 7·3 mm. thick and 40 mm. deep, or there may be a double spiral of two strips in parallel, each strip being 3·7 mm. thick.

Mean length of one series turn = 158 centimeters.

Weight series copper in one spool

$$= \frac{8{\cdot}5 \times 158 \times 2{\cdot}90 \times 8{\cdot}9}{1000} = 35 \text{ kgs.}$$

Total weight of series copper

$$= 8 \times 35 = 280 \text{ kgs.}$$

Resistance of 8 series coils at 60° Cent.

$$= \frac{8 \times 8{\cdot}5 \times 158 \times 0{\cdot}00000200}{2{\cdot}90}$$

$$= 0{\cdot}0074 \text{ ohms.}$$

Total watts lost in eight series coils at 60° C.

$$= 520^2 \times 0{\cdot}0074 = 2000 \text{ watts.}$$

Commutation.

As the armature conductors revolve, they alternately traverse magnetic fields of opposite polarities, and hence alternating electromotive forces are induced in them. Were the armature winding connected to slip rings, then the current flowing through the armature winding, the slip rings, the brushes, and the external circuit, would be an alternating current. But in the continuous-current dynamo, the winding is connected to a segmental commutator, by means of which the current in the external circuit is rectified. By the use of a moderate number of segments per pole, a continuous current, practically free from pulsations, is obtained. This may be found demonstrated, and discussed in all its bearings, in numerous text-books. It is a matter merely requiring careful study and thought. The conclusions are perfectly precise.

But there is a group of related phenomena of the very gravest importance to the designer, with relation to which, no approximation to a precise method of treatment has yet been devised. This group of phenomena comprises the occurrences in the coils short-circuited during commutation, and the occurrences at the brushes. A large amount of mathematical and experimental research has been devoted to this subject.*

* The following bibliography comprises the most important contributions to the discussion of the subject of sparking in commutating dynamos :—

Reid.—"Sparking: its Cause and Effects." Am. Inst. Elec. Engrs.; December 15th, 1897. Also, "The Electrician," February 11th, 1898.

Thomas.—"Sparking in Dynamos." "The Electrician," February 18th, 1898.

Girault.—"Sur la Commutation dans les Dynamos à Courant Continue." Bull. de la Soc. Int. des Electr., May, 1898, vol. xv, p. 183.

Dick.—"Ueber die Ursachen der Funkenbildung an Kollektor und Bürsten bei Gleichstrom-dynamos." Elek. Zeit., December 1st, 1898, vol. xix, p. 802.

Fischer-Hinnen.—"Ueber die Funkenbildung an Gleichstrom-maschinen." Elek. Zeit., December 22nd and 29th, 1898, vol. xix, pp. 850 and 867.

Arnold.—"Die Kontactwiderstand von Kohlen und Kupferbürsten und die Temperaturerhohung eines Kollektors." Elek. Zeit., Jan. 5th, 1899, vol. xx, p. 5.

Kapp.—"Die Funkengrenze bei Gleichstrom-maschinen." Elek. Zeit., Jan. 5th, 1899, vol. xx, p. 32.

Arnold and Mie.—"Ueber den Kurschluss der Spulen und die Kommutation des Stromes eines Gleichstromankers." Elek. Zeit., February 2nd, 1899, vol. xx, p. 97.

H. M. Hobart.—"Modern Commutating Dynamo Machinery, with Special Reference to the Commutating Limits." Proc. Inst. Elec. Engrs., 1901, vol. 31, p. 170.

Alexander Rothert.—"Wie viel Kollektorlamellen soll eine Gleichstrommaschine haben?" Elek. Zeit., 1902, Heft 15, p. 309.

Emil Dick.—"Funkenlose Kommutirung." Elek. Zeit., 1902, Heft. 18, p. 396.

E. Arnold.—"Beitrag zur experimentellen Untersuchung von Gleichstrommaschinen." Elek. Zeit., 1902, Heft. 25, p. 469.

Karl Pichelmeyer.—"Zur Theorie der Stromwendung." Elek. Zeit., 1902, Heft. 29, p. 623.

Franklin Punga.—"Beitrag zur Theorie der Stromwendung." Zeit fur Elek., 1902, Heft. 30, 31, 32.

Friedrich Eichberg.—"Ueber kompensirte Gleichstrommaschinen." System Deri, 1902, Heft. 37, p. 817.

Alexander Rothert.—"Beitrag zur Theorie der Stromwendung." Elek. Zeit., 1902, Heft. 39, p. 865.

P. Prenzlin.—"Ueber funkenfreies Kommutiren des Stromes von Gleichstrommaschinen mit Kohlenbursten bei Vor—und Rucklauf der Maschine und konstanter Bürstenstellung in der neutralen Linie." Elek. Zeit., 1902, Heft. 43, p. 933.

Karl Czeija.—"Kommutationsvorgänge in Gleichstrommaschinen." Sammlung Elektrotechnischer Vorträge, Stuttgart, Ferd. Enke, 1903.

Adolf Railing.—"Ueber Kommutierungsvorgänge und zusätzliche Bürstenverluste." Sammlung Elektrotechnischer Vorträge, Stuttgart, Ferd. Euke, 1903.

Karl Pichelmeyer.—"Die Stromwendung in Kommutirenden Maschinen." Zeit. fur Elek., 1904, Heft. 1, p. 1.

Franklin Punga.—"Hilfspole fur Gleichstrommaschinen." Zeit. fur Elek., 1904, Heft. 4.

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From the designer's point of view, the subject presents itself somewhat as follows: —

A single armature turn, connected to two adjacent segments, is shown in Fig. 48. Prior to coming into the position of short-circuit under the brush, it has been carrying a current of, say, 100 amperes in one direction. Immediately after emerging from the position of short-circuit, it will be carrying a current of 100 amperes in the opposite direction. The change must take place sparklessly. With this end in view, the brushes may be set at such a point on the commutator, that during the time when the coil is short-circuited, it will be traversing a magnetic flux of such direction as to tend to reverse the current in the coil. But this tendency must be sufficiently strong to overcome the reactance voltage set up in the coil itself by the decreasing current. This reactance voltage is greater, the greater the current in the coil when it arrives at the position of short-circuit under the brush; *i.e.*, it is greater the greater the load. Hence a stronger reversing field is required the greater the load. At no load, a very slight forward lead to the brushes will bring the short-circuited coil into a strong reversing field. But at no load, no reversing field is required, since there is no current and hence no reactance voltage to be overcome; and if the brushes are given more than a very small forward lead, sparking will ensue in consequence of the current induced in the coil while short-circuited, for this current must be broken when the coil leaves the brush, *i.e.*, when it emerges from the position of short-circuit. At a high load, when a strong reversing field is required to overcome the large reactance voltage, the field has been so distorted by armature interference, that a very large lead of the brushes may be necessary in order to bring the short-circuited coil into a sufficiently strong reversing field. Hence all that can be accomplished by this so-called "electromagnetic commutation," is to choose a brush position so far forward as possible without incurring sparking at no load, and to rate the machine at that load which does not cause sparking in this position; for it is now many years since the practice of permitting different brush positions for different loads has been abandoned.

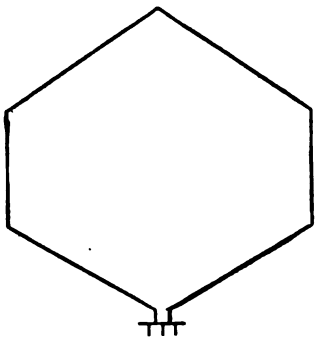

Fig. 48.

The *resistance* of the brush also assists in checking the current originally flowing in the coil. Owing to the unsatisfactory nature of the "electromagnetic commutation," where, as we have seen, the means upon which we rely become weakened in proportion as they should be strengthened, it is, when possible, better to set the brushes in the geometrical neutral point, and, abandoning all trust on "electromagnetic commutation," merely design the winding with so low a reactance voltage at full load as to preclude the possibility of sparking.

The Estimation of the Reactance Voltage.

Several turns are generally simultaneously undergoing short circuit under the brushes. The eight conductors constituting the group A in Fig. 49, are simultaneously short-circuited: the four upper ones at a negative, and the four lower ones at a neighbouring positive brush. Between two adjacent commutator segments, there is, in the case represented, only one turn. The change in magnetic flux due to the reversal of the current in these eight turns in the short time during which the coils are passing under the brush, sets up in any one turn a voltage which we may designate as the *reactance voltage*. If permitted to exceed certain limits, the reactance voltage will cause sparking. The first quantity to determine, is the flux due to the magnetomotive force of a given current in the short-circuited turns. Rough experimental determinations for customary types of design, made with a view to obtaining a basis for such estimations, have shown that there will be set up

4·0 c.g.s. lines per ampere-turn per centimeter of "embedded" length, and

0.8 c.g.s. lines per ampere-turn per centimeter of "free" length.

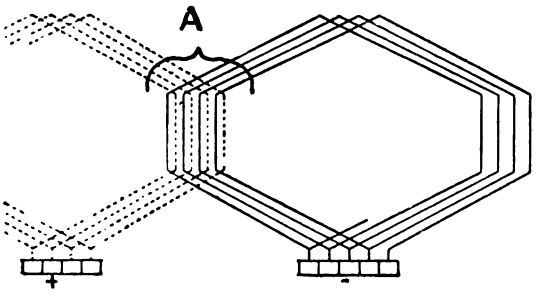

Fig. 49.

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One important difference must be pointed out between the exposed end connections and the embedded portion, namely: In the embedded portion, or more exactly, that portion of the face conductors parallel to the shaft, the conductors short-circuited under the positive brush, lie over or near (according to the nature of the winding, and also according to whether the pitch is so chosen as to yield a short or long-chord winding), those simultaneously short-circuited at the negative brush; whereas the two groups of corresponding *end-connections* are located separately. This is shown in Fig. 49.

Hence the magnetomotive force, acting in the short-circuited coil, is twice as intense for the effective length as for the end connections.

As "embedded length" and "free length" respectively, are designated the slot enclosed portion, and the end connections, including with the latter that portion of the conductors parallel to the shaft, not strictly iron-clad, *i.e.*, that portion corresponding to the ventilating ducts and the insulation between the laminations. In modern ventilated designs, this makes a marked difference, the "effective" length of laminations often constituting less than 70 per cent. of the length of armature core over all.

In this "free" portion, where the conductors are parallel to the shaft, the magnetomotive force is also twice as intense per centimeter of length as for the end connections. This is taken into account in the choice of 0.8 c.g.s. lines per centimeter as the constant for the "free" length.

The inductance of the "free" length may, in high-speed machines, amount to as much as 40 per cent. of the total inductance.

Let

l = inductance in henrys,

and n = number of changes of current direction, in cycles per second. Assuming that the current follows a sine rate of change, then the reactance, R, is obtained by the following formula:—

$$R = 2 \pi n l \times 10^{-8}.$$

n (the cycles per second) $= \frac{1{,}000\ A}{2\ b}$, where

A = peripheral speed in metres per second, and

b = length of arc of brush contact in millimeters.

$$\text{Hence } R = \frac{1{,}000 \cdot \pi A l}{b}$$

For a current strength of C amperes per turn we have

Reactance voltage $= R C = 2 \pi n l c \times 10^{-8}$.

The mean length of one armature turn is equal to

$$3 \tau + 2 \lambda_n,$$

the "free" length being equal to 3τ, and the "embedded" length to $2 \lambda_n$.

Lines per ampere-turn per centimeter of "free" length = 0·8,

Lines per ampere-turn per centimeter of "embedded" length = 4·0,

Lines per ampere-turn for "free" length = $0{\cdot}8 \times 3 \tau = 2{\cdot}4 \tau$, and

Lines per ampere-turn for "embedded" length = $4{\cdot}0 \times 2 \lambda_n = 8{\cdot}0 \lambda_n$.

Let the number of turns per segment $= q$.

Let the "number of simultaneously short-circuited conductors per group" (as shown at A in Fig. 49) $= r$.

Then

Lines per *ampere* for "free" length

$$= \frac{r}{2} \times 2{\cdot}4 \tau,$$

$$= 1{\cdot}2\ r\ \tau,$$

Lines per *ampere* for "embedded" length

$$= 8{\cdot}0\ r\ \lambda_n,$$

Total lines per ampere linked with short-circuited coil $= r\ (1{\cdot}2\ \tau + 8{\cdot}0\ \lambda_n)$,

Inductance per segment

$$= l = \frac{q\ r\ (1{\cdot}2\ \tau + 8{\cdot}0\ \lambda_n)}{10^8},$$

Reactance per segment

$$= 2 \pi n l = \frac{1{,}000\ \pi A l}{b},$$

$$= \frac{\pi A q r (1{\cdot}2\ \tau + 8{\cdot}0\ \lambda_n)}{b \times 10^5}.$$

We may denote this as Method I. for the determination of the reactance. The first glance at this equation might lead to the conclusion that increasing b, the width of the brush, would decrease the reactance. This is not the case, for r, the number of simultaneously short-circuited conductors per group, increases with b. The presence of the polar pitch, τ in the numerator also imposes certain limits to the reduction of the reactance voltage by increasing the diameter and thereby decreasing λ_n; or rather, it makes the improvement somewhat less than would be expected, were this consideration of the inductance of the end connections overlooked.

DETERMINATION OF THE REACTANCE FOR THE 400 K.W. DYNAMO, BY METHOD I.

$A = 8{\cdot}65$.

$b = 16$.

$q = 1$.

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$r = 4 \cdot 9$ (width of segment plus insulation $= 6 \cdot 55$ mm. and $r = \frac{2\,b}{6 \cdot 55} = \frac{32}{6 \cdot 55} = 4 \cdot 9$).

$\lambda_n = 28$.

$\tau = 91$.

Reactance =

$$\frac{\pi \times 8 \cdot 65 \times 4 \cdot 9 \times (1 \cdot 2 \times 91 + 8 \cdot 0 \times 28) \times 10^{-5}}{16}$$

$$= 8 \cdot 33\ (109 + 224) \times 10^{-5}.$$

The values 109 and 224 are, respectively, proportional to the relative influences of the free and embedded lengths on the total reactance. Thus, in this case, they constitute respectively 33 and 67 per cent. of the total reactance.

Reactance = ·0277 ohms. Amperes per turn

$$= \frac{730}{8} = 91 \cdot 3$$

Reactance voltage at full load = $91 \cdot 3 \times \cdot 0277$ = 2·53 volts.

METHOD II. FOR THE DETERMINATION OF THE REACTANCE.

A better idea of the factors affecting the reactance per segment, is obtained by throwing the formula of Method I. into another form. For this purpose, one may proceed as follows :—

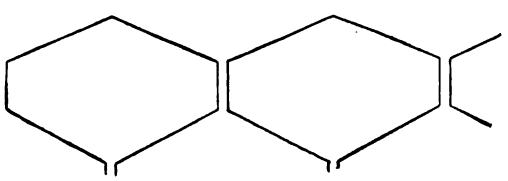

FIG. 50.

$\frac{r}{b}$ is obviously equal to

$$\frac{\text{Number of face conductors}}{\text{Circumference of commutator in millimeters}}$$

and

$\frac{Ar}{b}$ = Peripheral speed of commutator in meters per second × No. of face conds.

÷ Circum. of comm. in millimeters

$$= \frac{\text{R.P.M.}}{60{,}000} \times \text{No. of face conductors.}$$

$$\therefore \text{Reactance per segment} = \pi\, q \left(\frac{\text{R.P.M.}}{60}\right) \times \text{No. of face conds.} \times (1 \cdot 2\,\tau + 8 \cdot 0\,\lambda_n) \times 10^{-8}$$

Let H = Number of parallel circuits.

„ P = Number of poles.

„ T = Number of turns in series between brushes.

Then :

Number of face conds. = 2 H T

and $\frac{\text{R.P.M.}}{60} = \frac{2\,N}{P}$

(where N = periodicity in cycles per second).

Reactance per segment =

$$\pi q \left(\frac{2\,N}{P}\right)(2\ H\ T)\,(1 \cdot 2\,\tau + 8 \cdot 0\,\lambda_n) \times 10^{-8}$$

$$- \pi\, q \left(\frac{H}{P}\right)(4\ T\ N)\,(1 \cdot 2\,\tau + 8 \cdot 0\,\lambda_n)\,10^{-8}$$

Now $E = 4\ T\ N\ M\ 10^{-8}$

where E, T, N and M are the quantities defined on p. 176 of "Technics" for February, 1904 (Vol. I., No. 2.);

$$\therefore \frac{E}{M} = (4\ T\ N)\ 10^{-8}$$

$\therefore$ Reactance per segment

$$= \pi q \left(\frac{H}{P}\right)\left(\frac{E}{M}\right)(1 \cdot 2\,\tau + 8 \cdot 0\,\lambda_n).$$

Let total current output of armature = C. Then

$$\text{Current per arm. conductor} = \frac{C}{H}$$

and

$$\text{Reactance voltage} = \left(\frac{C}{H}\right) \times (\pi q) \times \left(\frac{H}{P}\right)\left(\frac{E}{M}\right) \times (1 \cdot 2\tau + 8 \cdot 0\,\lambda_n)10^{-8}$$

$$= \left(\frac{\pi\, q}{P}\right)\left(\frac{EC}{M}\right)(1 \cdot 2\,\tau + 8 \cdot 0\,\lambda_n)$$

$$= \frac{(8\,\pi\, q)\,(E\,C)\,(\lambda_n + 0 \cdot 15\tau)}{P\,M}$$

$$= 8\,\pi\,\frac{(\text{Turns per segment})\,(\text{Output of armature})\,(\lambda_n + 0.15\,\tau)}{(\text{Number of poles})\,(\text{Flux entering armature per pole})}$$

This latter formula is, in principle, identical with that proposed by Mavor on p. 223, Vol. XXXI. of *Proc. Inst. Elect. Engrs.*

To calculate the full load reactance voltage of the 400 k.w. dynamo, by Method II., one would proceed as follows :—

Turns per segment = 1.

Output of armature = 400,000

$\lambda_n = 28$ $\quad 0 \cdot 15\,\tau = 0 \cdot 15 \times 91 = 13 \cdot 6.$

$(\lambda_n + 0 \cdot 15\,\tau) = 28 + 13 \cdot 6 = 41 \cdot 6.$

Number of poles = 8.

Flux entering armature per pole = 21,800,000 c.g.s. lines.

$\therefore$ Reac. voltage at full load

$$= \frac{8 \times \pi \times 1 \times 400{,}000 \times 41 \cdot 6}{8 \times 21{,}800{,}000}$$

$$= 2 \cdot 40 \text{ volts.}$$

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The 5 per cent. discrepancy between this value (2·40 volts) and the value obtained by Method I. (2·53 volts), is due to the 5 per cent. difference between internal and terminal voltage. The exactness of expression by which this discrepancy could be avoided, would not be justified in estimations of so rough a nature as must necessarily be those relating to the reactance voltage. A study of the construction of the formulæ to which Methods I. and II. lead, is very instructive, and shows clearly the general lines of design essential to obtaining a low reactance voltage.

METHOD III. FOR THE DETERMINATION OF THE REACTANCE VOLTAGE.

The problem may be set forth in still a third very instructive form :—

The formula arrived at in Method II. is readily changed to

Reac. voltage per seg.

$$= 8\,\pi\,q\,\frac{E\,C}{P\,M}\,\lambda_n\left(1 + 0{\cdot}15\,\frac{\tau}{\lambda_n}\right)$$

Let B_A = Average density over the peripheral surface of the armature core.

$$\therefore B_A = \frac{P\,M}{\pi\,D\,\lambda_n} \quad \therefore P\,M = \pi\,D\,B_A\,\lambda_n$$

Let Q = No. of "ampere conductors" per centimeter of armature periphery.

$$\therefore Q = \frac{2\,T\,C}{\pi\,D} \quad \therefore C = \frac{\pi\,D\,Q}{2\,T} \text{ and}$$

$$E\,C = \frac{E\,\pi\,D\,Q}{2\,T}$$

$$\therefore \frac{E\,C}{P\,M} = \frac{E\,\pi\,D\,Q}{2\,T\,\pi\,D B_A\,\lambda_n} = \frac{E\,Q}{2\,T\,B_A\,\lambda_n}$$

Then,

Reactance voltage per segment $= 8\,\pi\,q$

$$\left(\frac{E\,Q}{2\,T\,B_A}\right)\left(1 + 0{\cdot}15\,\frac{\tau}{\lambda_n}\right)$$

$$= 4\,\pi\left(\frac{q\,E}{T}\right)\left(\frac{Q}{B_A}\right)\left(1 + 0{\cdot}15\,\frac{\tau}{\lambda_n}\right)$$

$\frac{E}{T}$ = Average volts per armature turn.

$\frac{q\,E}{T}$ = Average voltage per coil = e.

$\therefore$ Reactance voltage

$$= 4\,\pi\,e\left(\frac{Q}{B_A}\right)\left(1 + 0{\cdot}15\,\frac{\tau}{\lambda_n}\right).$$

This formula, which is due to R. S. McLeod, is very instructive in having as factors :—

e, the average voltage per coil,

Q, the ampere conductors per centimeter of periphery,

B_A, the average density over the peripheral surface of the armature core, and

$\frac{\tau}{\lambda_n}$, the ratio of armature pitch to nett core length.

APPLICATION OF METHOD III. TO THE CALCULATION OF THE FULL LOAD REACTANCE VOLTAGE OF THE 400 K.W. DYNAMO.

$$e = \frac{550}{99} = 5{\cdot}55.$$

$$Q = \frac{91{\cdot}3 \times 1584}{230\pi} = 200.$$

$$B_A = \frac{8 \times 21\,800\,000}{\pi \times 230 \times 28} = 8600.$$

$$\frac{\tau}{\lambda_n} = \frac{91}{28} = 3{\cdot}25 \quad \left(1 + 0{\cdot}15\,\frac{\tau}{\lambda_n}\right) = 1{\cdot}49.$$

Reactance voltage $= 4 \times \pi \times 5{\cdot}55 \times \frac{200}{8600} \times 1{\cdot}49 = 2{\cdot}42$ volts.

Any one of these three methods, when carried out in the form of a tabular specification, leads quickly to the desired result; but each throws interesting and different light upon the aspects of the problem.

(To be continued.)

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ALLOTROPIC MODIFICATIONS OF IRON.

By T. M. LOWRY, B.Sc.

THE extraordinary effects produced by the association of a little carbon with metallic iron, and the delicate shading of properties that can be produced by softening, chilling and tempering, have been known and made use of from the very earliest times; but it is only in recent years that the investigations of Osmond, Roberts-Austen and others have elucidated the complex problem presented by this series of alloys. The discovery that iron is trimorphous, and the accurate determination by Roberts-Austen of the transition-temperatures, laid the foundations for the scientific study of the alloys of iron; and on this basis all the more important properties of these alloys can be accounted for. γ-Iron, which is stable above 890°C, appears to possess all the properties of the hardest chilled steel, whilst α-iron, which is stable below 755°C, is simply a soft, magnetic, pure wrought iron. The properties of β-iron, which is stable between 890°C and 755°C, are not very fully known, but are to some extent intermediate between those of α and γ-iron.

The only important alloys of iron are those produced by associating it with elements that are isomorphous with γ-iron, but not with α or β-iron. Thus, solid γ-iron will form mixed crystals containing up to two per cent. of carbon, but the whole of this is thrown out of (solid) solution when the γ-iron passes into α-iron, as carbon is quite insoluble in this modification of iron. The effect of associating carbon with iron is, however, to greatly increase the range of temperature within which γ-iron is stable: in presence of 0·8 per cent. of carbon it does not begin to change directly into α-iron above 690°C. Even more pronounced effects are produced by alloying with manganese and nickel, either with or without carbon. The self-hardening steels, the properties of which were described in the February number of this journal, are simply alloys in which the lower limit of stability of γ-iron is brought down almost to atmospheric temperatures by associating it with carbon and manganese, and the numerous commercial applications of nickel steel depend on the fact that the limit of stability of γ-iron is steadily lowered by the addition of nickel, until in an alloy containing about 35 per cent. of nickel the transition-temperature is approximately 0°C.

The second important characteristic of the alloys of iron depends on the property possessed by the associated elements of reducing the rate at which the different modifications of iron are converted one into another. Thus γ-iron, which, when pure, cannot be obtained at ordinary temperatures, as it changes into α-iron immediately below the transition temperature, is obtained with the utmost ease by chilling a steel containing only a small percentage of carbon: when once brought down to atmospheric temperatures, it only softens extremely slowly. If, however, a chilled steel tool becomes hot in working, the rate of change from γ into α-iron increases and the tool becomes soft. In the self-hardening steels the transition-temperature is reached, and the γ-iron becomes stable.

The remarkable properties of steels containing about one part of nickel to two of iron are due to the fact that the conversion of γ into α-iron is just beginning at ordinary temperatures. The non-expansive alloys which were referred to in our April issue, owe their unique properties to the fact that α-iron occupies a greater volume than γ-iron; but whereas in pure iron the expansion takes place sharply at the transition-temperature, in the non-expansive alloys it is spread over a large range of temperature, *and just counterbalances the normal contraction due to fall of temperature.*

The elastic properties of nickel-steels are quite as remarkable as their non-expansive properties, and promise to lead to an even greater demand for them. γ-Iron is far more rigid than α-iron, and has a much larger modulus of elasticity. There is, therefore, a large decrease in passing from γ-iron to α-iron, and in the non-expansive alloys this decrease, instead of taking place abruptly, is spread over a wide range of temperature, and more than counter balances the normal increase due to fall of temperature. The result is that alloys containing from 29 to 45 per cent. of nickel have an altogether unique *positive* temperature coefficient of elasticity, whilst two alloys (having approximately the compositions indicated) will have a modulus of elasticity which does not vary with the temperature. Whilst the non-expansive alloys render it unnecessary to compensate for expansion in clock-pendulums, their elastic properties promise to effect an even more remarkable revolution in the watch-making industry, since by using a nickel steel hair-spring of suitable composition, it will be unnecessary to employ any form of compensated balance-wheel.

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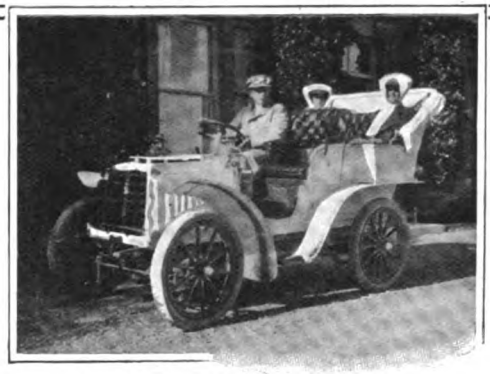
THE MODERN MOTOR CAR.



PART II.

By WILFRID J. LINEHAM, M.I.C.E., M.I.M.E., M.I.E.E.

Illustrated with Original Diagrams by the Author.

MY last article was occupied, at the outset, with an attempt to impart a general notion of the *chassis* of a modern petrol-driven pleasure car, by reference to typical examples: incidentally the relative advantages and disadvantages of belt, chain, and shaft (or live-axle) driving were referred to. The consideration of details of the mechanism followed, commencing with the engine: the importance of multiple cylinders, and the economy of high speed being insisted upon. The question of engine balance naturally occurred at this stage, and the paper concluded with descriptions of carburettors, and an account of the various modes of electric ignition at present on the market.

Continuing our examination of the engine details, we now arrive at

THE GOVERNOR

with which all car engines are now fitted. Formerly it was the custom to cause the exhaust valve to be automatically closed thereby; but a much more sensitive result is nowadays obtained by permitting the governor to throttle the mixture, as was mentioned in describing the Crossley carburettor. The general method adopted may be further made clear by reference to Fig. 16, which shows the Murray governor, as fitted to the "Albion" car. The governor shaft is driven from the engine shaft, and as the balls fly out with increased speed they act upon a lever B which presses upon the spindle of the throttle valve V, thus reducing the supply of air and gas. A wedge W, however, intervenes, which may be adjusted by means of a hand lever L. If this lever be lifted to its highest position the governor is later in its action, and a greater car speed results; but if the wedge be pressed down, the mixture is throttled at a lower speed, for the governor then acts more quickly on the valve. Thus, the governor may be set to hold the car at any desired speed, or, as it is said, to "follow up" the desires of the driver, and that in a most ingenious manner.

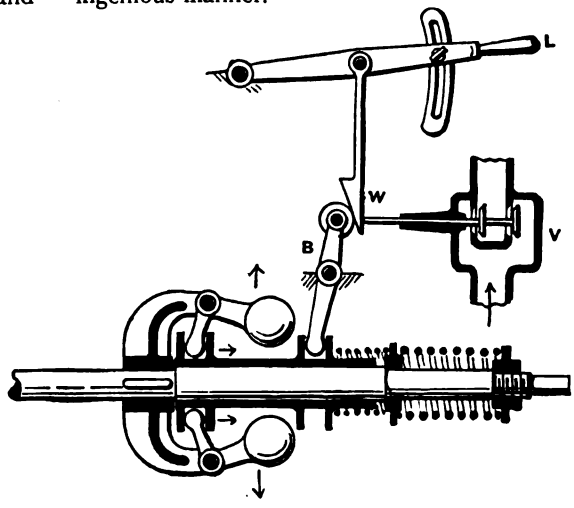


FIG. 16.—THE MURRAY GOVERNOR.

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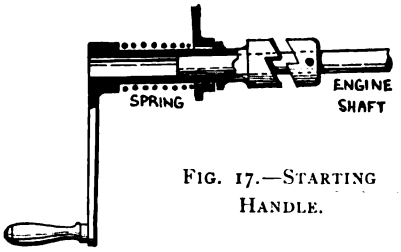

FIG. 17.—STARTING HANDLE.

STARTING THE ENGINE.

It is one of the defects of all internal-combustion engines, that the piston cannot be started by the mere admission of the working gas, as is done with the steam engine. This is because the charge itself has to be drawn in by the action of the piston, before ignition can take place; not to speak of the compression that must be further given before the mixture can be advantageously exploded.

Two remaining adjuncts of the engine must yet be described. The exhaust gases escape with some violence and consequent noise, which is minimised by conducting the gases from the exhaust outlet to a cylindrical vessel known as

THE SILENCER,

which is carried either at the side (Fig. 2) or the rear (Fig. 1) of the car. Various methods have been adopted in making satisfactory silencers: sometimes merely by causing the gases to traverse backward and forward in a cylinder along controlling passages; and at others by the introduction of common pebbles as obstructors and distributors of the shock. That silencer is most perfect, which eliminates noise so far as possible, without causing undue back pressure upon the engine; and as the Stanley silencer has been very successful, I

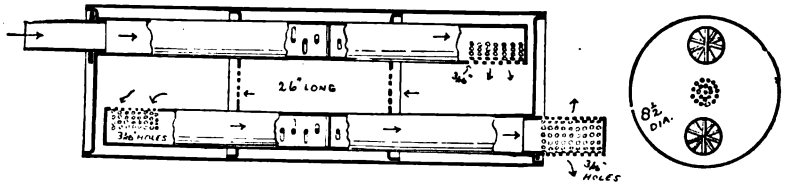

FIG. 18.—THE "STANLEY" SILENCER.

have given a section of it in Fig. 18 to show its construction. The gases entering on the left are met by a large number of cross-pin bafflers, and are compelled to traverse a number of fine holes when passing from the upper to the lower tube. Further resistance is caused by the diaphragm plates, which are pierced only by holes at their centres; and the final exit of the gases is again through small holes.

Another necessity in petrol engines is the cooling of the cylinders. Even under the best

For these reasons a starting-handle must be fitted loosely to the engine shaft, as in Fig. 17. The handle is also seen at the front of the car in Fig. 1. On its boss, the handle carries a right-handed clutch, which can be made to engage with a corresponding projection fixed to the engine shaft; but engagement is prevented by the action of a spring, except when it is desired to start. To use the handle most easily, the compression should be prevented for the first stroke or two, either by lifting the exhaust valve or opening a "compression cock" at the top of the cylinder. So soon, however, as an explosion takes place on the turning of the handle, the exhaust valve is dropped or the compression cock closed, when the engine takes up its own work, and the handle springs back out of gear. In every case the spark must be retarded to its fullest extent until the engine is well started. I find that, at present, the most usual custom is to omit the opening of the exhaust valve or compression cock, a long handle being used in order to gain the leverage necessary to perform the compression. This custom is followed, in spite of the risk of a damaged elbow from a back-fire.

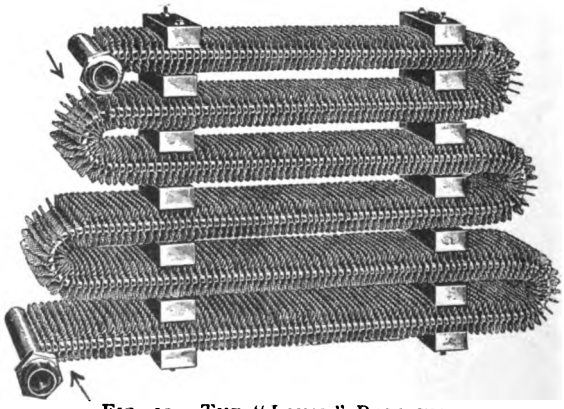

FIG. 19.—THE "LOYAL" RADIATOR.

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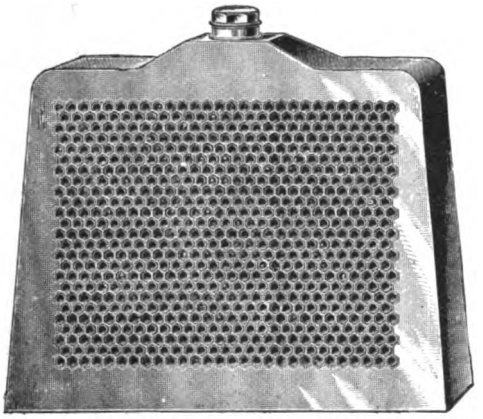

FIG. 20.—THE "ALBANY" HONEYCOMB RADIATOR.

conditions an excessive amount of heat is created by the explosions: all of this, unfortunately, cannot be used to do work, and some must therefore be transmitted to the atmosphere. Air cooling of the cylinders, assisted by plates or fins upon the cylinder body, is compulsory in the case of bicycles, but is now practically obsolete as regards the larger cylinders of motor cars, on account of its inefficiency. Some device must be adopted to absorb the surplus heat of the cylinders and distribute it to the air, and that as quickly as possible; for if there are many misfires, the heat developed is enormous, and the exhaust

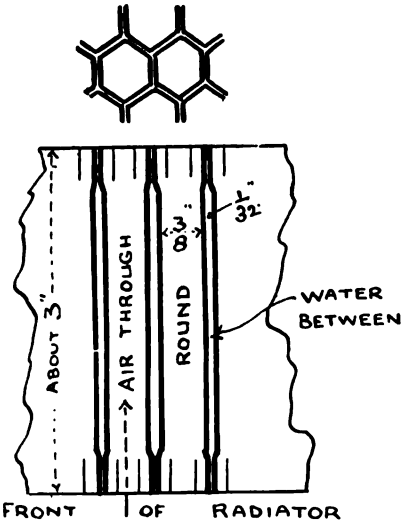

FIG. 20A.—TO ILLUSTRATE THE CONSTRUCTION OF THE HONEYCOMB RADIATOR.

pipe soon becomes red-hot. Some day this heat will undoubtedly be largely saved, for its loss involves a great waste of energy. When we remember that of all the heat in the charge at ignition, only one quarter does work and three-quarters is lost in water jacket cooling and exhaust gases, there is certainly *something* to be saved. Up to now no better intermediate distributor of heat has been found than cold water; and this must be constantly circulated from a water tank, through the cylinder jackets, and then to the front of the car through a coil of pipes known as

THE RADIATOR,

of which the "Loyal" pattern, Fig. 19, has been till recently the most used. The pipes are covered with radiating discs or fins that materially help to carry away the heat from the radiator. A newer form of radiator, known as the "honeycomb" pattern, is just

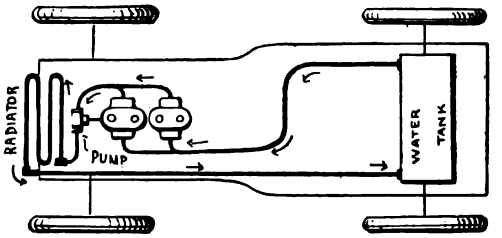

FIG. 21.—THE WATER CIRCULATION.

now being extensively adopted, both on account of its neatness, and the belief in its greater cooling capacity. The name follows from its hexagonal air tubes, of which a large number are used. Fig. 20 shows the general form, which is that of a surface condenser, where air, the cooling medium, passes through the tubes from front to back, the water

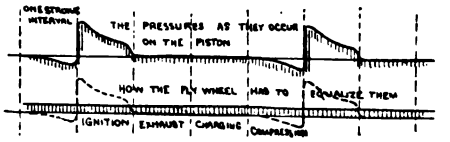

FIG. 22.—THE FUNCTION OF THE FLY WHEEL.

circulating between them. Fig. 20A shows the construction. Thin brass tubes of circular section are expanded into hexagons at their ends, and are soldered together by dipping the whole surface of the radiator to a depth of $\frac{1}{4}$ in. into a bath of molten tin. The space between the tubes is only about one millimeter wide, which is one objection, as causing clogging; and there is some tendency for the soldered ends to leak. It is also the practice with this radiator to drive a fan near its inner surface, as is shown in Fig. 7 ("Technics," No. 4) which is of considerable value when the car is standing.

The most convenient place for the water

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tank is at the rear of the car, although long pipes are a necessary consequence of this arrangement, which is shown in Fig. 21. Of course, circulation must be kept up, and for this purpose a small rotary or centrifugal pump has been commonly applied; but somehow there have been great difficulties with this little organ, so that there have been several recent attempts to dispense with it altogether. To effect this result, it is necessary to place the tank at some height above engine and radiator, so as to create two columns of water, the one hot and of light weight, while the other is cooler and heavier. The method can scarcely be described as satisfactory, especially as the water becomes hotter and hotter, and no doubt more attention will be given to perfecting the pump. In any case the water soon gets warm, and must, at stated intervals, be renewed.

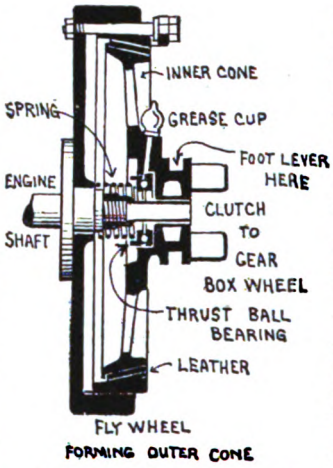

FIG. 23.—THE "ARGYLL" FRICTION CLUTCH.

Having completed the description and suggestively by the diagram at Fig. 22. For a long time now it has also been customary to locate the driving or friction clutch in the fly-wheel, and I may refer my readers for explanation to Fig. 23, which shews the "Argyll" clutch. The internal spring keeps the inner cone constantly pressed against the outer one, except when relieved therefrom by means of a foot lever: a surface of leather is placed between the two cones to obtain the necessary grip. This material is undoubtedly a source of some trouble, having to be renewed at least once a year, so that some makers have introduced forms of "metal to metal" clutches, of which the Crossley clutch (Fig. 24) is a noteworthy example. Here the inner portion consists of two blocks or shoes, hinged at the upper pins to a central bracket, which is carried on a hollow shaft that engages by a claw clutch into the first gear wheel. A pair of toggle levers are

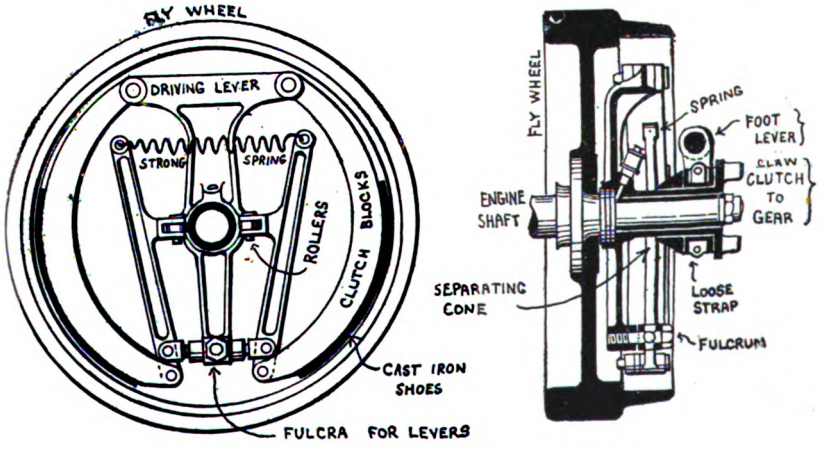

FIG. 24.—THE "CROSSLEY" FRICTION CLUTCH.

explanation of the engine proper, I shall now proceed to the rest of the car mechanism.

THE FLY WHEEL

belongs as much to the general mechanism as it does to the engine. It is a necessity to the latter wherever a four-stroke cycle is adopted, for the explosions occurring only at intervals of four strokes or two revolutions, a heavy rotating weight must be provided to equalise the crank effort. This is shown connected to the lower end of the blocks, and a strong spring unites their top ends so as to press the blocks outwards against the fly-wheel. To release the grip, a foot lever slides a cone inward, which pressing against the rollers, separates the levers at their upper extremities and draws the clutch blocks together. It will be further noted that the surfaces of the clutch are cylinders; and as they are of metal, they must be kept well oiled, so as to allow slipping

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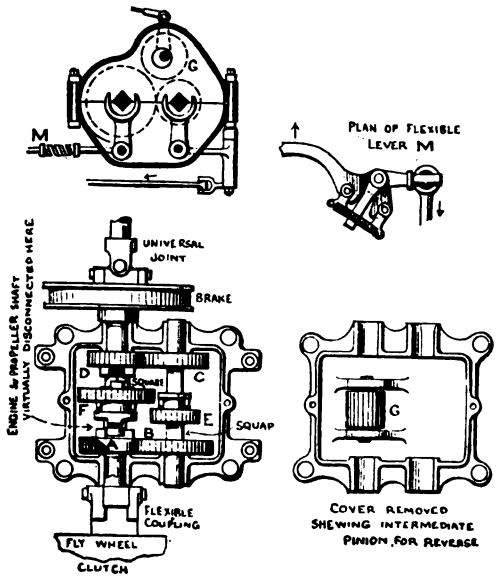

FIG. 25.—THE "ARGYLL" GEAR BOX.

on starting, or when slightly varying the speed.

After leaving the fly-wheel the engine shaft ends abruptly, and the so-called propeller shaft meets it; but is not directly connected, being only clutched thereto at the highest speed of the car, or when driving "solid," as it is termed.

THE GEAR BOX.

I have already explained the unfortunate necessity for the use of change-speed gear in petrol engines—unfortunate, not only on account of frictional loss, but because most of the buzzing noise associated with motor cars is due to the rattle of the gear wheels. Very few car drivers are content to drive with less than what they call "four speeds and reverse," three of which are provided by pairs of wheels and the fourth by direct driving: the reverse being obtained by the separate introduction of an intermediate wheel between the slow speed pair of wheels. As a matter of fact, any number of speeds may be arranged for: it only means an extra pair of wheels for every new speed, and an extra lever for operating them. I shall therefore content myself, as an illustration of the general principle, by showing how three speeds and reverse are provided for in the "Argyll" gear box. Referring to Fig. 25, a wheel A, connected by hollow shaft and flexible coupling to the fly-wheel, gears constantly with another wheel B on a second motion shaft of square section, and the rotation is transferred to the propeller shaft (which is also of square section at this point) by pairs of wheels C, D, or E, F, designed to provide for the first and second speeds of about 8 and 17 miles per hour; while the top speed of 25 miles is obtained by a solid drive as before mentioned. Firstly let it be understood that A is locked to the engine shaft: B and C are keyed to the second shaft: D is fixed to the propeller shaft, on which it runs freely; and E and F slide on square shafts. Thus, for first or lowest speed, E is slid into gear with F, and the drive is A, B, and E, F; for the second speed E and F are out of gear, but F is slid into clutch with D, thus driving as A B, C D; the third speed is procured by sliding F into clutch with A, so as to couple propeller shaft directly to engine shaft. To reverse, a wheel G is mounted in eccentric bearings, and the latter being rotated by a lever, the drive is A B, E G F, which gives an opposite rotation at slowest speed. The lever M for putting the clutches in gear is especially interesting. Being disjointed and reunited by a strong spring, the driver merely puts his hand lever "hard over," and the clutches find their connection by the aid of the spring. This is better than sliding teeth into gear, which it will be noted is only done regarding E and F at the slowest speed. It is further claimed that this gear box is the smallest on the market, which certainly seems to be the case.

After leaving the gear box, the propeller

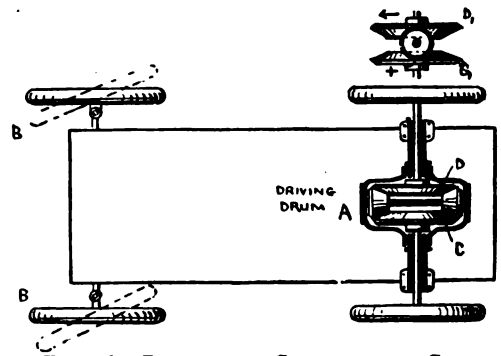

FIG. 26.—DIAGRAM OF COMPENSATING GEAR.

shaft goes rearward to drive either a chain shaft, as in Fig. 1; or the hind live axle, as in Fig. 2. In either case the speed is still further reduced; but while this is done entirely by chain on the one hand, the bevel or mitre wheels being equal: the reduction to live axle is obtained by the use of unequal bevel wheels, the smaller of which is of course

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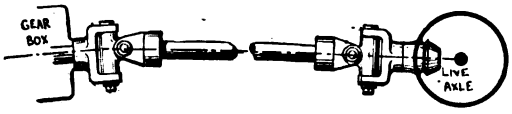

FIG. 27.—CONNECTION OF GEAR-BOX TO LIVE AXLE.

on the propeller shaft. This is clearly shown in Figs. 1 and 2 respectively. The bevel gear in either case is required for the purpose of changing the longitudinal drive into that of the cross shaft, but the connection to the latter is not immediate. The difficulty of turning corners when the wheel base is considerable occurred 40 years ago, in connection with traction engines; and the apparatus then devised has been transmitted to posterity, and used in the tricycle and the motor car. This mechanism I prefer to call

THE COMPENSATING GEAR,

though it is sometimes termed the "differential gear," and sometimes the "jack-in-the-box:" a simple diagram, Fig. 26, will best explain it. Imagine a drum A revolving freely on bearings, and carrying upon diametral studs two bevel pinions which gear respectively with two *separate* hind axles, one to each wheel. So long as the front wheels B B are guided straight forward, the four bevels rotate as one solid block, causing the road wheels to turn at equal rates in the same direction. But if the car be steered leftward, say, as shown by dotted lines, the hind wheel and bevel C tend to remain stationary, in which case D would revolve forward at double the speed of A, the smaller pinions serving as live rollers. What does really happen in the supposed case is that the left hind wheel, lying on the inner curve, turns less rapidly, and the right wheel more rapidly than A, with automatic correctness; and the arrangement of bevel wheels that does this is known as a reverted epicyclic train. Its application to traction engines was due to Aveling, of Rochester.

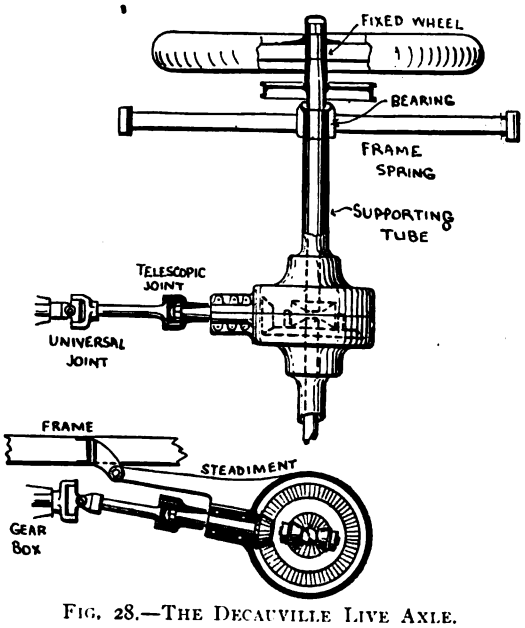

FIG. 28.—THE DECAUVILLE LIVE AXLE.

UNIVERSAL COUPLINGS,

known also as Hooke's joints, from the name of their old-time inventor, are introduced at various places and for specific reasons, but always for the purpose of making the propeller shaft flexible. In the first place, it is present-day custom to place such a joint between the engine and gear box: not because the gear shaft and engine shaft are ever seriously out of line, but merely to allow for the possible deflection of the frame as a whole. The remaining joints required depend entirely on the construction of the car. If the latter be chain-driven, as in Fig. 1, no further joint is needed; but if we adopt a live axle, either one or two joints of good construction must intervene, as in Fig. 27; for the gear box is fixed solidly to the frame, while the axle is mounted on springs, and the deflection of the latter causes the box to rise and fall relatively to the hind axle. Theoretically, two joints are best, for the inequality of angular rotation occasioned by the first is rectified by the second; but as the angular deviation is generally slight, such rectification is not needed. Advantage is taken of this fact in the Decauville gear, Fig. 28, where only one joint is fitted, that near the gear box; the axle apparently rising and falling round this as a centre. The steadying arm prevents undue bending

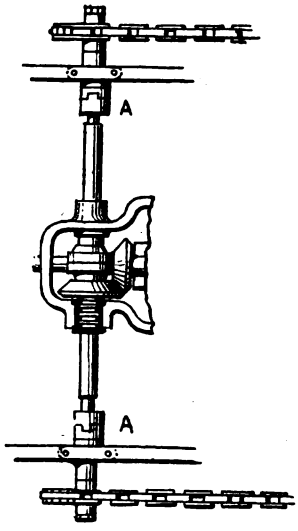

FIG. 29.—THE CHAIN PINION SHAFT.

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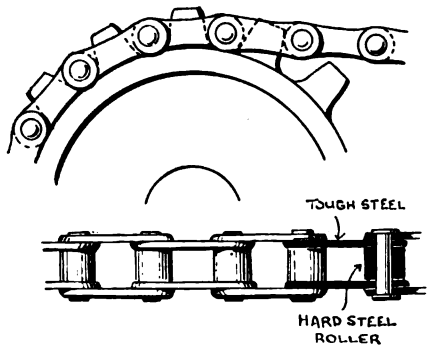

FIG. 30.—THE "BRAMPTON" CHAIN.

on the shaft, but necessitates the introduction of a telescopic coupling of square section. Universal joints must be protected by air-tight flexible coverings, and need to be well oiled.

THE LIVE HIND AXLE

is always in two lengths, as already explained, and also shown in Figs. 26 and 28. It will be

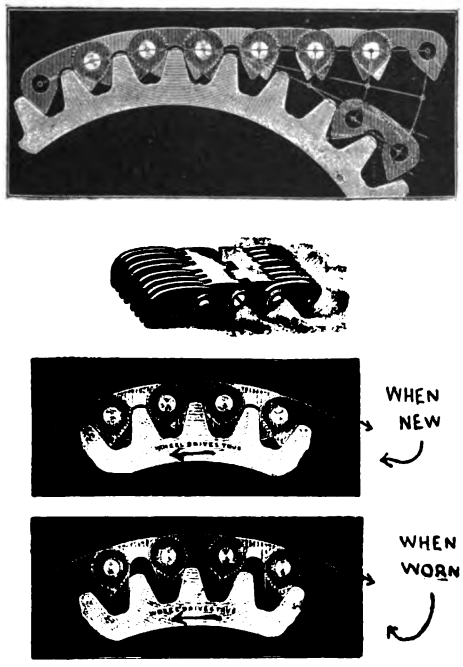

FIG. 31.—THE "HANS RENOLD" CHAIN.

seen that the bearings are carried in a long tube, which is supported on the car springs and prevented from rotation by the steadying arm. In the latest pattern of the Decauville car the axles can be separately withdrawn through the road wheels, to which they are loosely clutched on the outside.

Reverting now to the chain-driven car, it has already been shown that the chain shaft is in two pieces, just like the live axle, so as to facilitate steering by introduction of compensation gear. Further flexibility is often provided by the clutches A, A, Fig. 29, the projecting portions of the shaft being well supported by long bearings fixed to the frame. Continuing, we arrive at the chain pinions, which are coupled to the sprocket wheels on the hind wheels by

THE CHAIN,

of which the usual form adopted is that known as the "Brampton." Its construction is very

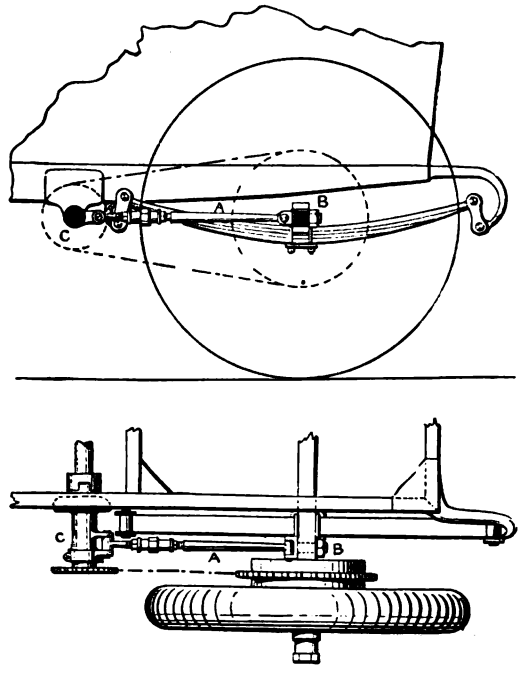

FIG. 32.—ADJUSTMENT OF CHAIN.

well understood in its application to the bicycle, but there are some small points of difference that are worth mentioning. It will be seen, on looking at Fig. 30, that the inner edges of the chain plates are rounded, which facilitates their entrance upon the teeth. These links are of tough steel, so as to resist shock; but the steel of the rollers is strong and hardened, so as to thoroughly prevent wear. I may also mention the "Renold" chain, Fig. 31, which is most interesting from a scientific point of view, for it is designed to overcome the greatest difficulty of all in the use of chains—the non-correspondence of chain links and wheel teeth on account of

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the stretch of the former. This chain has the capacity, in short, as shown in Fig. 31, of automatically adjusting itself to an increased length, by riding further up the teeth: it has only two objections that are at all serious—its increased weight and its expense. It has been used with great success in the Wolseley car as a connection from the engine shaft to the gear box, and the arrangement has much to recommend it.

Slackness of chains between the wheel centres, if considerable, is remedied by withdrawing one or more links; but, if less important, is met by the adjustment in length of a screwed rod, A, Fig. 32. This rod serves as a stiff stay between the chain shaft C and the hind axle B, and when the chain has lengthened enough to cause much slack, the central nut (provided with right-and left-hand threads) is turned round to increase the distance apart of B and C. Such lengthening naturally puts the spring links in less symmetrical positions, so that it can be only used for lengths less than one chain link.

VECTORS AND GRAPHS AND THEIR PRACTICAL APPLICATIONS.

PART III.

By ELLIS H. CRAPPER, M.I.E.E.

PROBLEM V.

To Specify a Vector by its Rectangular Components, and to Represent a Vector Algebraically by the Symbolical Method.

HAVING shown that any vector may be resolved into two rectangular components, we may now consider how the x-component may readily be distinguished from the y-component, and also how they may be clearly defined—mutually perpendicular axes only being considered. Instead of stating verbally which component is being considered, it is usual to employ a distinguishing symbol; Prof. S. P. Thompson, for instance, in his work, "Polyphase Currents," introduces vertical and horizontal lines to distinguish the y and x-components, the horizontal line being attached to the letters denoting the x-component, and the vertical line to those of the y-component. Thus, the rectangular components of the vector OP (Fig. 1) are $\overline{OA}$ and $|OB$, and we may write

$$\text{Vector OP} = \overline{OA} + |OB$$

the sign of addition (+), indicating that $\overline{OA}$ and $|OB$ are the rectangular components of the vector OP. Steinmetz, however, has developed a system, expressing in symbols the mutual relationship of vectors represented by a phase diagram, known as the *symbolical method*, which has met with general acceptance and considerable application; so it is most important that the student should make an

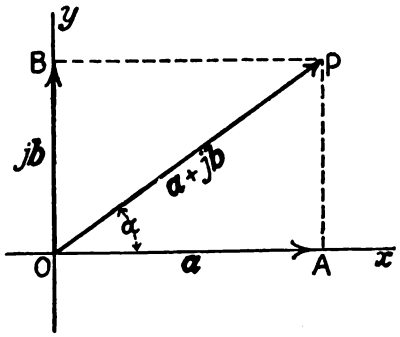

FIG. 1.

acquaintance with the principles of the method. In the simplest case, vectors are treated as the radii of circles, and are resolved into their rectangular components along two fixed axes of reference, one horizontal and the other vertical; a single small letter **a** (say) is employed to denote

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the x-component, and another letter **b** (say) with a symbolic letter j attached to it, for the y component: the clarendon type of letter being used in both cases. The letter j is introduced to indicate that the component to which it is prefixed is perpendicular to the other component. To specify the vector OP (Fig. 1) in this system, we simply write

$$\mathbf{P} = \mathbf{a} + j\,\mathbf{b} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

It may be mentioned here that this branch of modern mathematics—*i.e.*, vector algebra —is a modified form of *Quaternion analysis*, originally introduced by Sir W. R. Hamilton, which in its general form was used to some extent by Maxwell: at the present time vector algebra is used very considerably in the treatment of alternating current problems. For instance, the representation of any periodic function by means of a vector, tends to simplicity; since the polar co-ordinates, or the projections of the vectors upon two rectangular axes, enable the phase relationships existing between various factors to be depicted more clearly than by any other method.

If the tensor, or magnitude, of the vector **P** be p, then the magnitudes of the rectangular components are respectively

$a = p \cos \alpha$,
and $b = p \sin \alpha$;

so that the tensor of

$$\mathbf{a} + j\,\mathbf{b} = p\,[\cos \alpha + j \sin \alpha]; \quad . \quad . \quad . \quad . \quad . \quad (2)$$

the magnitude $p = \sqrt{a^2 + b^2}$ . . . . . (3)

The direction, or phase of a vector relatively to the x-axis is given by the angle α, such that

$$\tan \alpha = \frac{b}{a}, \text{ or } \alpha = \tan^{-1} \frac{b}{a} \quad . \quad . \quad . \quad . \quad (4)$$

It must be observed that the prefix j is *not* of the nature of a constant factor or multiplier, but rather that of an operator; consequently it does not form part of the magnitude or tensor of a vector, but indicates how the components are combined to obtain the magnitude of the vector. The expression $\mathbf{a} + j\,\mathbf{b} = p\,[\cos \alpha + j \sin \alpha]$ is an example of that type of a quantity termed a quaternion, since it consists of the product of a tensor, p, and the turning operator $[\cos \alpha + j \sin \alpha]$ which is known as a *versor*. A versor was defined by Hamilton as an operator which alters the direction of a vector without changing its length. A useful modification of the expression given in equation (2) has been introduced by Professor Jackson, who has suggested the idea of denoting $[\cos \alpha + j \sin \alpha]$ by cis α, when it is desired to express symbolically the operation which rotates a vector through an angle α. There are, therefore, several ways of expressing a vector algebraically by the symbolic method; thus we have

$$\begin{aligned} \mathbf{P} &= \mathbf{a} + j\,\mathbf{b} \\ &= p\,[\cos \alpha + j \sin \alpha] \\ &= p \text{ cis } \alpha. \end{aligned}$$

These principles are in perfect accordance with a well-known convention in common use in higher trigonometry, in which $\sqrt{-1}$ (the equivalent of j introduced by Steinmetz) is defined as a symbolical expression whose square is (-1), but which must not be considered a *quantity*, but a *symbol of operation*. In trigonometry, the expression $[\cos \alpha + j \sin \alpha]$ is often represented by $e^{j\alpha}$, which is an expression for a periodic function, since cos α and sin α, and therefore also $[\cos \alpha + j \sin \alpha]$ repeat their values every time α is increased by 2π; in other words, $e^{j\alpha}$ is a symbolical expression for a quantity which repeats its value every time α is increased by 2π, for which reason $e^{j\alpha}$ or $[\cos \alpha + j \sin \alpha]$ denotes a periodic function. $e = 2{\cdot}71828$ is the base of the Napierian system of logarithms. Furthermore, as α changes from 0 to 2π, no two values of $[\cos \alpha + j \sin \alpha]$ or $e^{j\alpha}$ are the same except the first and last; and when **a** function of α repeats every value in exactly the same order as α is increased by a certain value, it is said to be *periodic*.

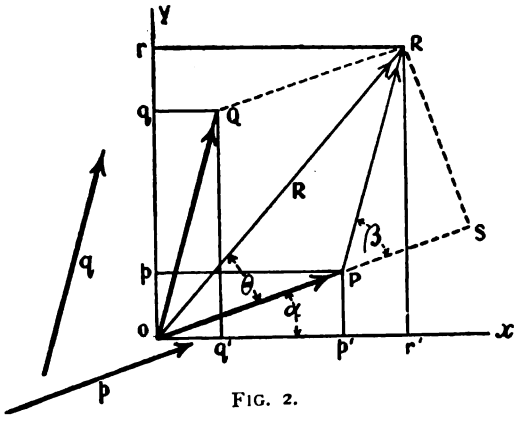

FIG. 2.

The principles of the symbolical method may very conveniently be applied to the summation and multiplication of vectors, and to denote the phase of a vector. Thus, the law of vector addition is obtained as follows: let it be required to obtain the algebraical expression of the vector sum of the vectors OP and OQ (Fig. 2). Clearly we have

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$$\mathbf{P}=\mathbf{a}+j\mathbf{b}=\overline{Op'}+\overline{Op}$$
$$\mathbf{Q}=\mathbf{a}_1+j\mathbf{b}_1=\overline{Oq'}+\overline{Oq}$$
$$\text{and } \mathbf{R}=\mathbf{P}+\mathbf{Q}=\overline{Or'}+\overline{Or}$$
$$=[\overline{Op'}+\overline{p'r'}]+[\overline{Op}+\overline{pr}]$$
$$\therefore\ \mathbf{P}+\mathbf{Q}=[\mathbf{a}+\mathbf{a}_1]+[j\mathbf{b}+j\mathbf{b}_1]$$
$$=[\mathbf{a}+\mathbf{a}_1]+j[\mathbf{b}+\mathbf{b}_1]. \quad .(5)$$

Similarly, the algebraical statement for the *difference* of two vectors **P** and **Q** is

$$\mathbf{P}-\mathbf{Q}=[\mathbf{a}-\mathbf{a}_1]+j[\mathbf{b}-\mathbf{b}_1]$$

The idea of j being an operator is capable of considerable extension; the meaning attached to it becomes more apparent when vectors in different positions are considered. Thus if the vector under consideration were negative, as shown by the dotted line PO in Fig. 3, the actual position of the line representing it would be in the third

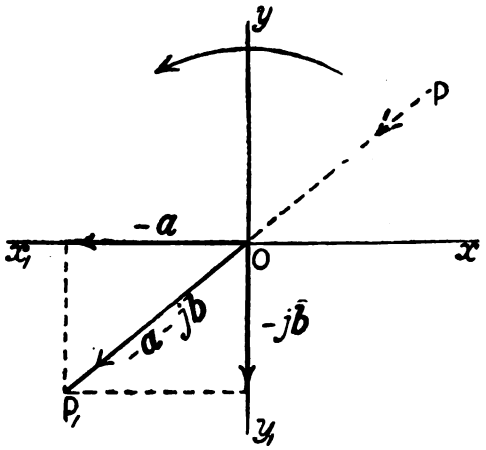

FIG. 3.

quadrant when referred to rectangular co-ordinates, as shown by the full line OP_1 in Fig. 3.

Since $\overline{OP_1}=-\overline{OP}$,

the symbolical expression of $\overline{OP_1}$ is obtained by multiplying the expression $(\mathbf{a}\times j\mathbf{b})$ by (-1)

$$\text{and } \overline{OP_1}=-\overline{OP}=-(\mathbf{a}+j\mathbf{b})$$
$$=-\mathbf{a}-j\mathbf{b} \quad \ldots\ldots (6)$$

the negative signs possess the usual geometrical interpretation of reversed direction, showing that the x-component (**a**) is to the left of O the point of origin, and the y-component (**b**) is below the zero line. Equation (6) is, therefore, the symbolical expression of a vector which has been rotated through π or 180° from a position in the first quadrant, in the positive direction or contra-clockwise. In other words, the reversal of the direction of a vector is indicated by multiplying it by (-1).

If a vector in the first quadrant be turned in the positive direction through $\frac{\pi}{2}$ or 90°, we must operate upon $(\mathbf{a}+j\mathbf{b})$ to obtain the rectangular components indicating the new position taken up, and this is readily done by prefixing j to $\overline{OP}$, since $\overline{OP}$ must be rotated through 90°, consequently (Fig. 4)

$$\overline{OP_1}=j(\overline{OP})=j[\mathbf{a}+j\mathbf{b}]$$
$$=j\,\mathbf{a}+j^2\mathbf{b}$$

a result which indicates that the effect of rotating $\overline{OP}$ through a right angle in the positive direction is the same as turning its original x-component through 90° into the position Op_1 along the y-axis, and the original y-component also through 90° into the position Op_2 along the x-axis.

But lengths to the left of O along the horizontal axis represent negative quantities, and are denoted by a single letter with the proper sign attached. Therefore, as in Fig. 4,

$$\overline{Op_2}=-\mathbf{b}$$
$$\text{and } j^2\mathbf{b}=(-1)\mathbf{b}$$
$$\text{from which } j^2=(-1), \text{ and } j=\sqrt{-1}$$

It thus becomes obvious that the properties of the imaginary quantity $\sqrt{-1}$ may be applied to j^2 or $j.j$, implying that the vector has been multiplied by $(\sqrt{-1})^2$ or (-1); or that the operator j has been used twice; in other words, the vector has been rotated through *two* right angles, or 180° in the positive direction. Therefore

$$\overline{OP_1}=j(\overline{OP})=j\mathbf{a}+j^2\mathbf{b}$$
$$=j\mathbf{a}-\mathbf{b} \quad \ldots\ldots (7)$$

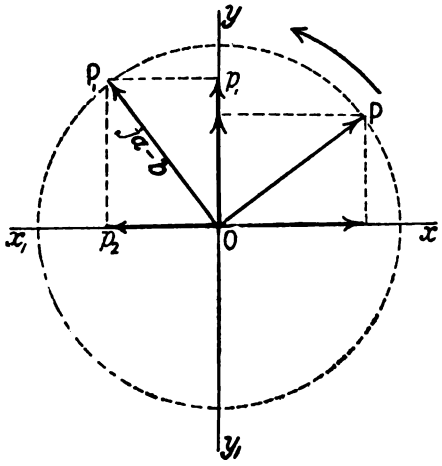

FIG. 4.

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in which (j **a**) simply means the vector **a** turned through 90° from the horizontal position, and $-$**b** is a vector which has been rotated from the vertical into the horizontal position, but to the left of O. $j\overline{OP}$ $= (j\mathbf{a}-\mathbf{b})$ therefore indicates a vector 90° in advance of the vector $OP = \mathbf{a}+j\mathbf{b}$. A lag of 90° is similarly $-j\overline{OP} = -j\mathbf{a}-j^2\mathbf{b}$ $= -j\mathbf{a}+\mathbf{b} = -(j\mathbf{a}-\mathbf{b})$.

Since $j^2 = (-1)$, we may in a similar way obtain equation (6) for the symbolical expression of the rotation of a vector through 180°. Obviously (see Fig. 3),

$$\begin{aligned}\overline{PO} \text{ or } -\overline{OP} &= j^2(\overline{OP})\\ &= j^2(\mathbf{a}+j\mathbf{b})\\ &= j^2\mathbf{a}+j^3\mathbf{b}\\ &= (-1)\mathbf{a}+(-1)j\mathbf{b} = -\mathbf{a}-j\mathbf{b}\end{aligned}$$

as before.

Similarly, if a vector OP in the first quadrant be rotated through three right angles or 270° into the 4th quadrant, the symbolical expression is $[-j\mathbf{a}+\mathbf{b}]$

It may here be noted that $j = \frac{1}{-j}$; since $j = \sqrt{-1}$,

$$\frac{1}{j} = \frac{1}{\sqrt{-1}} = \frac{\sqrt{-1}}{(-1)} = -j, \text{ or } j = \frac{1}{-j} \quad . \quad . \quad . \quad (8)$$

which indicates that if a vector be multiplied by $\frac{1}{j}$, (*i.e.*, be divided by j), the operation indicates the negative rotation of the vector through 90°. Also, a quantity to which the prefix j is attached is *imaginary*, consequently in the expression $\mathbf{P} = \mathbf{a}+j\mathbf{b}$

a is a *real* quantity,
and j**b** is *imaginary*.

When one of the two rectangular components of a vector is *real* and the other is *imaginary*, that expression is termed a *complex quantity*.

Collecting together the symbolical expressions of vectors in the different quadrants, we have

A vector in the 1st quadrant is $\mathbf{P} = \mathbf{a}+j\mathbf{b}$
„ „ 2nd „ „ $\mathbf{P}_1 = j\mathbf{a}-\mathbf{b}$
„ „ 3rd „ „ $\mathbf{P}_2 = -\mathbf{a}-j\mathbf{b}$
„ „ 4th „ „ $\mathbf{P}_3 = -j\mathbf{a}+\mathbf{b}$

and it is obvious that the position of a vector is clearly specified by its symbolical expression.

So far, we have only considered the operations corresponding to rotations through 90° or $\frac{\pi}{2}$, or through multiples of $\frac{\pi}{2}$; but the use of the symbolical method would be considerably restricted if the rotations of a vector through angles less than 90° could not be represented in a similar manner. Let us consider the case of the rotation of $\mathbf{P}_\alpha$ (*i.e.*, the vector $\overline{OP}$ (Fig. 5), which makes an angle α with the x-axis) through an angle β less than $\frac{\pi}{2}$. Let OP_1 denote the new position of the vector after it has been operated upon, then we may write

$$\overline{OP} = p\,[\cos\alpha + j\sin\alpha] = p\,\text{cis}\,\alpha$$
$$\text{and } \overline{OP}_1 = p\,[\cos(\alpha+\beta) + j\sin(\alpha+\beta)] = p\,\text{cis}\,(\alpha+\beta)$$

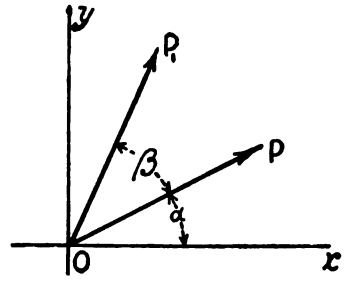

Fig. 5.

Now, cis $(\alpha+\beta)$ = cis $\alpha \times$ cis β. As this is an important relationship, it will be well to prove the statement.

$$\begin{aligned}\text{Cis}\,(\alpha+\beta) &= \cos(\alpha+\beta) + j\sin(\alpha+\beta)\\ &= \cos\alpha\cos\beta - \sin\alpha\sin\beta + j[\sin\alpha\cos\beta + \sin\beta\cos\alpha]\\ &= \cos\alpha\cos\beta + j[\sin\alpha\cos\beta + \sin\beta\cos\alpha] + j^2\sin\alpha\sin\beta\\ &= [\cos\alpha + j\sin\alpha][\cos\beta + j\sin\beta]\\ &= \text{cis}\,\alpha\,\text{cis}\,\beta\end{aligned}$$

By forming ratios, we have

$$\frac{\overline{OP}_1}{\overline{OP}} = \frac{p\,\text{cis}\,(\alpha+\beta)}{p\,\text{cis}\,\alpha} = \frac{\text{cis}\,\alpha\,\text{cis}\,\beta}{\text{cis}\,\alpha} = \text{cis}\,\beta$$
$$\therefore \overline{OP}_1 = \overline{OP} \times \text{cis}\,\beta = \overline{OP}\,[\cos\beta + j\sin\beta]$$

We therefore see, that to rotate a vector through an angle β, it is only necessary to multiply the complex quantity $(\mathbf{a}+j\mathbf{b})_\alpha$ or $[\cos\alpha + j\sin\alpha]$, which represents the vector in its original position, by the complex quantity $[\cos\beta + j\sin\beta]$ or cis β.

In a similar manner it may be shown that

$$\text{cis}\,(\alpha-\beta) = \text{cis}\,\alpha \div \text{cis}\,\beta = \frac{\text{cis}\,\alpha}{\text{cis}\,\beta}$$

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PROBLEM VI.

To obtain the product and quotient of two vectors.

It is required to obtain the vector product of any two vectors $\overline{OP}$ and $\overline{OQ}$ (Fig. 6), differing in phase by an angle β, when $\overline{OP}$ makes an angle α with the x-axis.

$$\text{Let } \overline{OP} = \mathbf{a} + j\,\mathbf{b}$$
$$\text{and } \overline{OQ} = \mathbf{a}_1 + j\,\mathbf{b}_1$$

then the product $\overline{OP} \times \overline{OQ}$ is

$$\begin{aligned}\mathbf{P} \times \mathbf{Q} &= (\mathbf{a} + j\,\mathbf{b})(\mathbf{a}_1 + j\,\mathbf{b}_1)\\ &= \mathbf{a}\,\mathbf{a}_1 + j\,\mathbf{a}\,\mathbf{b}_1 + j\,\mathbf{a}_1\,\mathbf{b} + j^2\,\mathbf{b}\,\mathbf{b}_1\\ &= [\mathbf{a}\,\mathbf{a}_1 - \mathbf{b}\,\mathbf{b}_1] + j\,[\mathbf{a}\,\mathbf{b}_1 + \mathbf{a}_1\,\mathbf{b}]\end{aligned}$$

which is interpreted to mean that the product of two vectors is another vector, the x-component of which is $[\mathbf{a}\,\mathbf{a}_1 - \mathbf{b}\,\mathbf{b}_1]$, and the y-component $[\mathbf{a}\,\mathbf{b}_1 + \mathbf{a}_1\,\mathbf{b}]$. In Fig. 6, $\overline{OM}$ is the vector which denotes the product of the vectors $\overline{OP}$ and $\overline{OQ}$. The phase angle which $\overline{OM}$ makes with the x-axis is equal to the sum of the phase angles α and $(\alpha + \beta)$. Since

$$\mathbf{P} = p \operatorname{cis} \alpha$$
$$\text{and } \mathbf{Q} = q \operatorname{cis} (\alpha + \beta)$$

the product

$$\mathbf{P}\,\mathbf{Q} = p\,q \operatorname{cis} \alpha \operatorname{cis} (\alpha + \beta)$$

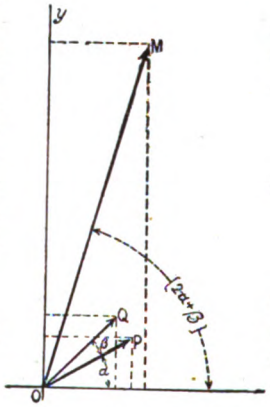

FIG. 6.

The tensor of the product $p\,q$ gives the measure of OM, which is equal to

$$\sqrt{(a\,a_1 - b\,b_1)^2 + (a\,b_1 + a_1\,b)^2},$$

and the phase angle made by $\overline{OM}$ with the x-axis is given cis α cis $(\alpha + \beta)$.

Now, cis α cis $(\alpha + \beta)$
$= [\cos \alpha + j \sin \alpha]\,[\cos(\alpha + \beta) + j \sin (\alpha + \beta)]$
$= \cos \alpha \cos (\alpha + \beta) + j \cos \alpha \sin (\alpha + \beta)$
$\quad + j \sin \alpha \cos (\alpha + \beta) + j^2 \sin \alpha \sin (\alpha + \beta)$
$= \cos \alpha \cos (\alpha + \beta) - \sin \alpha \sin (\alpha + \beta)$
$\quad + j\,[\sin \alpha \cos (\alpha + \beta) + \cos \alpha \sin (\alpha + \beta)]$
$= [\cos (2\,\alpha + \beta) + j \sin (2\,\alpha + \beta)]$
$= \operatorname{cis} (2\,\alpha + \beta)$

In the case of the quotient we have

$$\frac{\overline{OP}}{\overline{OQ}} = \frac{\mathbf{P}}{\mathbf{Q}} = \frac{\mathbf{a} + j\,\mathbf{b}}{\mathbf{a}_1 + j\,\mathbf{b}_1}$$

multiplying and dividing by $(\mathbf{a}_1 - j\,\mathbf{b}_1)$ we obtain

$$\begin{aligned}\frac{\mathbf{P}}{\mathbf{Q}} &= \frac{(\mathbf{a} + j\,\mathbf{b})(\mathbf{a}_1 - j\,\mathbf{b}_1)}{(\mathbf{a}_1 + j\,\mathbf{b}_1)(\mathbf{a}_1 - j\,\mathbf{b}_1)}\\ &= \frac{\mathbf{a}\,\mathbf{a}_1 - j\,\mathbf{a}\,\mathbf{b}_1 + j\,\mathbf{a}_1\,\mathbf{b} - j^2\,\mathbf{b}\,\mathbf{b}_1}{\mathbf{a}_1^2 - j^2\,\mathbf{b}_1^2}\\ &= \frac{\mathbf{a}\,\mathbf{a}_1 + \mathbf{b}\,\mathbf{b}_1}{\mathbf{a}_1^2 + \mathbf{b}_1^2} + j\,\frac{\mathbf{a}_1\,\mathbf{b} - \mathbf{a}\,\mathbf{b}_1}{\mathbf{a}_1^2 + \mathbf{b}_1^2}\end{aligned}$$

which means that the quotient of two vectors is another vector, the x-component of which is

$$\frac{\mathbf{a}\,\mathbf{a}_1 + \mathbf{b}\,\mathbf{b}_1}{\mathbf{a}_1^2 + \mathbf{b}_1^2}$$

and the y-component is

$$\frac{\mathbf{a}_1\,\mathbf{b} - \mathbf{a}\,\mathbf{b}_1}{\mathbf{a}_1^2 + \mathbf{b}_1^2}$$

In this case the phase angle of the quotient vector is negative, and equal to the difference of the two angles, since

$$\begin{aligned}\frac{\mathbf{P}}{\mathbf{Q}} &= \frac{p \operatorname{cis} \alpha}{q \operatorname{cis} (\alpha + \beta)}\\ &= \frac{p}{q} \operatorname{cis} [\alpha - (\alpha + \beta)]\\ &= \frac{p}{q} \operatorname{cis} (-\beta)\end{aligned}$$

Examples.

(1) Draw the vectors:—$[4 + j\,3]$; $[3 - j\,6]$; $[-j\,5 + 4]$.

(2) Determine the vectorial sum of $[3 + j\,8] + [3 - j\,4] + [1 + j\,5]$.

(3) Prove that the magnitude of the product of the two vectors $(\mathbf{a} + j\,\mathbf{b})$ and $(\mathbf{a}_1 + j\,\mathbf{b}_1)$ is $\sqrt{a^2 + b^2} \times \sqrt{a_1^2 + b_1^2}$

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SOME APPLICATIONS OF SCIENCE TO BOOT AND SHOE MANUFACTURE.

By E. SWAYSLAND, Principal Instructor in Boot and Shoe Manufacture, Northamptonshire County and Northampton Borough Councils.

THE development of the making of footwear from an art craft, depending for results upon the skill of the individual workman, to a highly complicated manufacture, with the intricate sub-divisions of labour and mutually dependent organisation of the modern shoe factory has been so rapid that many of the empirical methods of the craftsman have been carried into the factory; retarding the attainment of that exactitude from which the best results are obtained under the modern factory system. The craftsman accustomed to obtain his results by dexterous straining of the material, has little faith in the exact provision for minute details, and generally has not had the training likely to lead him to assume that mental attitude which makes for exactitude in anything. This looseness of thought is one of the difficulties if dealing with workmen responsible for precision in a subdivision of a trade, but which will probably be removed when the effects of the recent trend of education have had time to show results. The coming workman, accustomed in the schools to the mental processes exercised in the detection and precise recording of observed facts, will no doubt carry these habits into the workshop, and make for an exactitude which the present-day craftsman appears to find difficult to appreciate. This scientific method of considering a subject is of more value to the workman than a faculty for answering questions in science subjects. At present there are very few signs that the young men who come into the factory and the class room have received any training in observation, or have any knowledge of any science capable of application to manufacture.

Consequently the empirical methods of the craftsman are commonly in use in the shoe factory, particularly in those departments where the elasticity of the material permits explanations of defects, and suggestions of remedies, based upon the neglect of, or the manner of execution of, old-time craftsmanship. This is frequently the case where the effect desired is obtained by the comparative position, in the finished boot, of two parts, one only of which is strained during the process of manufacture; as for instance, the relation between the leg of a boot and the portion strained round the last. Under the old method any defect would be remedied by some extra straining by the craftsman; in many cases the work was simply dragged into shape. Under the new system the design must be so arranged that the desired effect is developed by the ordinary processes of the factory. This necessitates the designing of the parts with something approaching scientific exactitude, and, although some effort has been made in this direction, there are great possibilities of the practical application of scientific principles to boot manufacture. Much, in a disconnected way, has been done. There are probably few trades that have more varied or more involved applications of scientific principles; the applications of geometry and mechanics have an immense range, some of the practical solutions of the problems are of great ingenuity and practical value. The faults are generally owing to the inability to recognise some elementary scientific fact, and to ascribe the defects to indifferent workmanship.

We find this in the production of a "standard" pattern by the method usually adopted in the workshop and taught in the trade schools. The problem is apparently simple, but when investigated presents some points prolific of error. The "standard" is expected to produce an "upper" which, when made up in the finished boot, will have its front line at a given angle with the plane upon which the boot stands; this angle is usually referred to as the "inclination." It is also generally assumed to be at right angles with the ground. The leg of the boot is expected to have a certain relation with the foot portion, determining the curvature between the ankle and the front and the back of the design; this is termed the "pitch." It is evident that the particular degree required can be obtained if any one position can be determined; it becomes merely a matter of amounts.

In most cases the pattern cutter assumes that the opposite sides of the last are identical; a fallacy evident upon inspection. It

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is, however, true that the average surface area of the sides may nearly equal, and under the old methods that was the excuse for cutting both sides alike. But it is evident that the shape is very different, and that it is too much to expect them to be dragged into shape under the factory system. Therefore, these sides should have separate patterns constructed to them.

The actual pattern of the side of a last is termed a "forme"; the operation of producing this may be accomplished in several ways; the two most practical methods are shown in Fig. 1. It will be observed that these formes simply produce an approximate

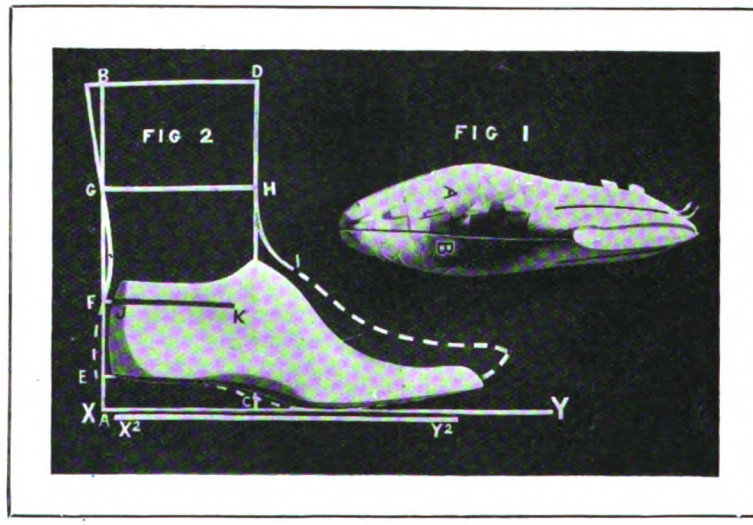

Fig. 1.—Top View of Last, showing the Difference between the Sides A, the Slotted Method, and B, the Solid Method of Producing a Forme.

Fig. 2.—The Conventional Method of Constructing a Standard Pattern, showing the Incorrect Position of the Forme in relation to the Last, and the Suggested New Lines.

representation of the curved surface of the last when developed upon the flat. The precise reproduction is obviously an impossibility, and therefore the most suitable method for certain purposes should be selected. The method shewn upon the outer side of the last A is known as the "mitre" or slotted method; it consists of cutting in strong thin paper a profile of the last, but about an inch larger each way. Slots normal to the outline, at about half an inch apart and one inch deep, are cut along the front, bottom, and back of this forme, and it is then fastened upon the side of the last, so that it lies as flatly as possible along the line of least curvature. This line is indicated by the line shown at the side of the last, and would be continued forward to the toe end. Alternate spaces between the slots are turned back, so that the centre line of the last may be seen, and the overlaying paper cut away, or the place where it crosses the centre line marked in pencil. This being repeated up the back and along the edge of the bottom, the marked or cut pieces are turned back and the other slips turned down and treated in the same manner. Seeing that a flat surface cannot be made to envelop any surface of double curvatures, the forme produced is only approximately correct; and seeing that the line along the side of the last does nearly correspond with the surface, there must be some deviation in the line length elsewhere. This evidently occurs along the line where the slots are corrected to the centre and the bottom edge. It is evident that some deviation must occur, seeing that these slips pass over a longer line than their united length would upon the flat, if not cut to allow of opening. This method then produces a shape that is nearly correct along the line of least curvature—technically, the counter line—but is incorrect in the length of the curve passing up the centre. If the whole of the slips are drawn across the centre line together, the extent of the error can be seen. It is obvious that if the ends of the slips are separated

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when folded down, there is a loss of length in the curve equal to the amount by which they are separated. This defect is usually remedied in the shop by increasing the line length of the front by lowering the toe end of the forme; it is the only practical method generally known. It is a particularly good method for light materials that will easily stretch to the profile form of the last above A B.

The method shewn at B is the "solid forme" method. The rough shape is produced as in the mitre method, but without the slots. The paper being pressed over the surface and marked in a solid line where it crosses the centre, and the edge of the last, all the excess measurement is distributed over the centre of the forme. This is apparent by the appearance of the forme upon the last in Fig. 1 B. The line length of this forme is evidently too great along the line of least curvature. This, although a defect in the standard, is rather easily remedied by cutting the sectional parts correct in length of counter, while retaining the advantage of the correct length of profile curves.

These formes are connected by construction lines to the leg portion, as shewn in Fig. 2. The portion determined by the forme is shewn in dotted line. It is connected to the construction lines by being arranged upon the ground line X Y, so that upon the heel being raised the height the line is intended to provide for, the back portion touches at the point F.

The construction lines in general use are shown in Fig. 2. The line X Y represents the plane upon which the last stands. The line A B is the pitch line, and is attached to the forme at the point F. The point G is the pitch point, its position in relation to the point F determines the relative position of the leg of the boot to the foot portion. The position at G represents the normal pitch; amounts in either direction would be referred to as a forward or backward pitch—specifying the amount. This line is also the girth line for the ankle measure; the line G H being taken parallel with X Y and terminating at half the girth in the point H. A vertical line C D through this point gives the normal "inclination," which is a right angle. In practice it is usual to draw the lines A B, C D at half the ankle girth apart. The curves F G and H I represent the art of the pattern cutter. Below the points I F the dotted outline represents the "forme."

If the whole of the surface of the forme compared to the profile was developed upward this would be a correct method; but it is evident that this cannot occur, and that some part must be developed downward—and, therefore, some portion of the lower outline of the forme might pass below the base line X Y. This has been found in practice, and allowances made for it, but no system which provides for this condition has come into general use. Probably the omission to provide for the upward turn of the last from the centre to the edge has disguised to a small extent the inaccuracy in the other direction—and hence two inaccuracies to some extent counterbalanced.

But it must be evident that if several lasts of the same profile, but of different widths, be placed in the position as shown in Fig. 2 the development of the width of the forme must be in both directions, and therefore some portion must come below the lower profile of the last. This being, I think, evident; the problem is to devise some means of connecting the forme, or its equivalent, to the construction lines, so that we can obtain the correct relative position between the leg portion and the ground, and the last.

The solution appears to require the determination of a line that will have a constant relation between the pitch line and a line upon the last, and which is also easy to accurately connect with the forme.

This line is found at the counter line along the surface of least curvature, shown at J K. If we assume this line to be parallel with the base, and we make a corresponding line upon the forme, we have a means of attaching the forme to the construction lines in a manner that is independent of the base line. This holds even if we wish to take into account the relative substance of the sole, and the consequently higher elevation of the heel; the extra amount would simply be added, which would be equal to assuming a lower X Y, as X_2 Y_2; in any case, the line J K would be taken parallel with the plane upon which the last or boot stands.

This line, which I shall refer to as the "forme" line, should be marked upon the last at a certain proportionate distance from the edge of the seat and, as mentioned before, level with the ground. This distance may conveniently be taken at one-fifth of the length of the last; a scale of proportions should be part of the working kit of the pattern designer. Its position may be marked upon the forme either by cutting a slot along the counter through which the line upon the last would be seen, or by the use of transparent paper, as in Fig. 1, A B.

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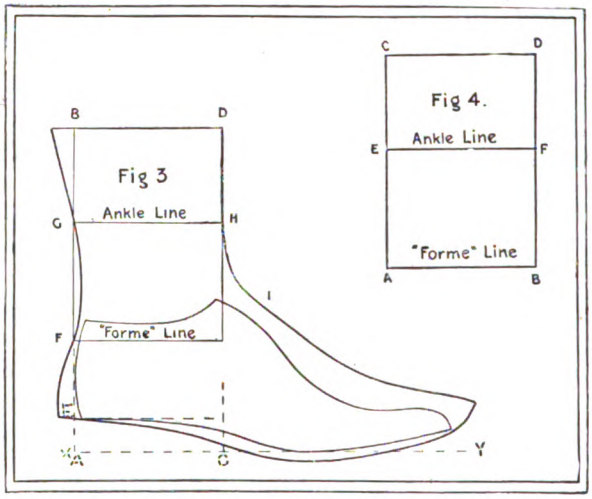

FIG. 3.—THE NEW METHOD OF CONSTRUCTING A "STANDARD," SHOWING THE NEW CONSTRUCTION LINES AND THE DISCARDED X Y AND A E F.

FIG. 4.—THE ESSENTIAL LINES BY THE NEW METHOD.

Seeing that the forme line is taken parallel to the ground, a line at any angle to that would be equivalent to taking it from the X Y. This is shown in Fig. 3, the line A B is at right angles to the X Y and to the forme line from F. As the forme is attached to the construction lines by the point F and the forme line, there is no use for any of the lines below F. These discarded lines are shown in dotted line, those used in the new method in solid line.

These may now be arranged in a much simpler manner, the essential lines being shown in Fig. 4. In this the point A represents the point F; the line A B—the "forme" line, acts as the X Y; the pitch line, A C, and the line of inclination, B D, being taken from it exactly as from the X Y, but with the proportionate differences in the measurements below the counter point omitted.

In this figure the position of the last and the forme line upon it is shown in its relation to the plane upon which the last stands, this being the first operation in working to the new system. The seat should be elevated to the position it will occupy in the finished boot, the forme line should then be drawn level with the base. This must be performed with some care.

A forme should be cut to each side of the last and attached to the construction lines shown in Fig. 4. The line A B should be drawn equal to half the girth of the ankle measure, and the lines A C, B D drawn at the required angle to it; this will include the space required by the ankle line E F. The point E should be three-tenths of the length of the last from A. The distance defining the height of the leg at C is most conveniently taken from the edge of the forme.

Fig. 5 shows the method in practice. The construction lines being drawn as described, the forme is placed upon it so that the forme line is precisely upon A B when the back curve touches the point A. The outline A J I H G is then drawn and the remainder of the pattern A E, D F G finished.

By laying each of the formes upon the construction lines the relation between the developed surface of the sides can be compared. I do not know of any other method by which this could be done. The outer side is shown here by a thick line; the relative points upon the last are shown at G, H. As these points are some distance apart when the patterns are on the flat, although taken from the same point in each case on the last, it is evident that the distance from A to G is greater upon the inner than on the outer side.

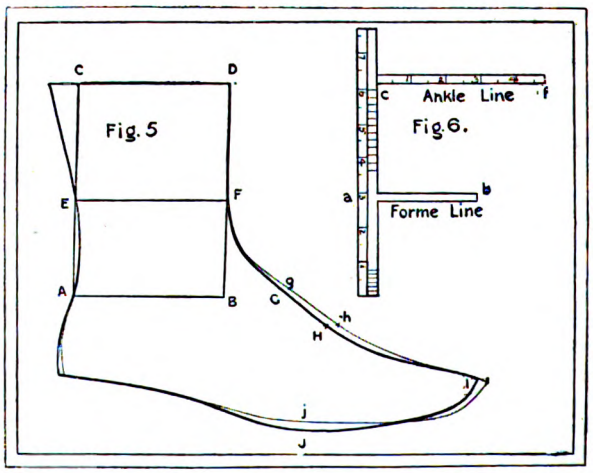

FIG. 5.—APPLICATION OF THE PAIR OF "FORMES" TO THE CONSTRUCTION LINES.

FIG. 6.—SUGGESTED NEW TOOL TO DRAW CONSTRUCTION LINES TO SCALE.

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It is then apparent that if both sides are cut the same size, the seams must be twisted equal to G *g*, H *h*. That the whole of the difference is from A to G, H is proved by the distance H J being the same in both formes.

The practical application of this would be assisted by the use of a tool constructed as shown is Fig. 6. It could be made by any handy man; in fact, the construction of scales of this character should be part of the work of the up-to-date pattern designer. The forme line A B is the constant line in the tool; the counter distances being measured downward, the ankle line upward. The measurements could conveniently be taken from the lower edge of the forme line; the inner edge of the tool being used for the line A E C. The position of the pitch points could be arranged upon a scale, as shown at *e*. By sliding the tool along the line A E C, lines parallel with the forme line could be marked, the length required being taken from the scale upon the ankle line *e f*. The tool might conveniently have an inch scale upon the opposite edge for the purpose of determining the height of the leg.

The proportionate differences required at the different points can be found by determining the length of the line compared to the length of the last, and then dividing the difference made in the lengths of the lasts between size and size into the same proportion.

This is easily ascertained by constructing a scale, as shown in Fig. 7. The base line A B should be made the length of the smallest size in a set; the line B C at right angles to A B should be long enough to take the longest size when measured diagonally from A towards C. C D, A D complete the rectangle. The side B C should be divided into the differences made in the lengths of lasts; usually one-third of an inch for British trade, and two-thirds of a centimeter for other places The sides A B, C D may be divided into the proportions most likely to be required. In this case the line A B is divided into sixteen, the line C D into ten parts; lines from each of these divisions, parallel to B C and A D, must be drawn across the scale. Lines should also be drawn from each of the divisions on B C to the point A. Where the lines crossing from A B to C D cut the radiating lines from A they divide them into the proportionate grade between sizes at the line length measured from A. For instance, we could determine the grade that should be marked upon the scale in Fig. 6 for the counter heights by taking the differences made by the two-tenths line as it crosses the scale. Similarly, the five-tenths represent the full differences between the grade of ankle heights, but as the counter grade has to be deducted, we deduct the two-tenths from the five-tenths, measuring towards D, and ascertain the proportion for that scale.

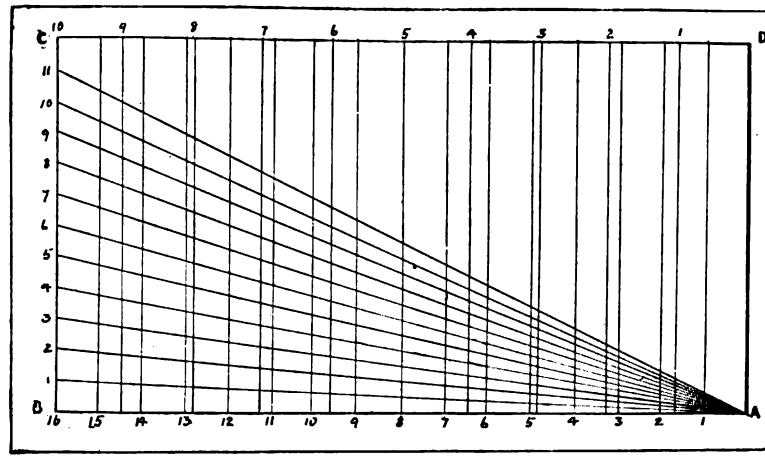

FIG. 7.—SCALE FOR DETERMINING THE PROPORTIONATE DIFFERENCES BETWEEN SIZES IN DIFFERENT PARTS OF PATTERNS.

Any intermediate proportions may be determined by drawing other lines, or by assuming their direction. The student—and the workman—who has not attempted this method of solving problems in proportion should experiment with a scale of this kind They are a very valuable assistance to the pattern designer; and so readily made that no workman—certainly no student—should be unfamiliar with the production of them.

(To be continued.)

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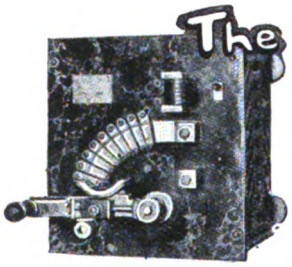
MOTOR STARTING RESISTANCES.

Some Points that Govern their Efficient Design.

By FRANCIS H. DAVIES.



The motor starting resistance, although a most useful piece of apparatus, has, until recently, been much neglected; that is to say, it has been designed in a very casual manner, mostly by rule of thumb, and with very little regard to the theoretical conditions which should be complied with.

In the space available it is impossible to go into the subject with the full detail that it deserves, but the following notes may be taken as an indication of the lines upon which successful design must be carried out. Many of the remarks, such as those dealing with the material and coiling of wires, apply to all resistances, for whatever purpose used.

The metals and alloys most in use for resistance wires are galvanised iron, galvanised steel, German silver, platinoid, manganin, and various other alloys for which special advantages are claimed.

While the cost of some of these differs widely per lb. of wire of the same gauge, the specific resistance varies also in the same direction—that is, the higher the price, the greater the resistance of a given weight of wire of a particular gauge. The consequence is, that for any given resistance the price of the wire works out much the same, whatever material is used. It must, however, be borne in mind that the longer the wire for any given resistance, the greater the cost of the frame and coiling; and also that it is generally desirable for a starting resistance to take up as little room as is compatible with efficient heat radiation. Considering these points, it is obvious that under most conditions the metal with the highest specific resistance will make the cheapest and neatest job, provided always that its price is within reason, and that it is suitable to withstand the strains set up by alternate heating and cooling. Some substances, such as German silver, become crystallised and brittle after subjection to heat, and eventually give trouble by breaking off; while others, such as iron, become soft, with the result that the spiral, by its own weight, tends to draw out at the top and close up at the bottom—a very undesirable state of things, considering the fact that, for safety, resistance coils should be rigid under all conditions of use.

Incidentally it may be mentioned that, although vertical spirals are mostly used, owing to the diminished liability to make accidental contact with one another in that position, horizontal spirals are best for dissipating heat, as the convection currents of air then have a larger scope.

We now come to the question of the gauge of wire. It may be safely stated that under no conditions should a wire of less than No. 24 B.W.G. be used. Such wires are mechanically very weak, and liable to fracture at joints; and in addition, the coils are affected greatly by the vibration of running machinery, which sets up perpetual strains, and sometimes even causes contact to be made between neighbouring spirals. On the other hand, No. 8 B.W.G. may be taken as the opposite extreme; sizes over this are expensive and difficult to coil. When a large current-carrying capacity is required, two or more spirals should be arranged in parallel, instead of using a single spiral of very thick wire. The correct gauge may be ascertained from the table on the next page, but it should be noted that the current values given may be safely doubled for starting rheostats, as these are only subjected to heating for short intervals of time. When the resistance is also to act as a regulator, the values given must be adhered to.

The current densities for the different materials specified are as follows:—

	amperes per sq. in.
Galvanised iron . . .	about 2,000
German silver . . .	„ 1,400
Platinoid }	„ 1,000
Manganin }	

After the gauge has been settled, the very important point of coiling arises. With a little thought it becomes obvious that different gauges of wires must be coiled into spirals of different diameters, lengths, and pitches, not only for mechanical reasons of stability, but also from the point of view of dissipation of heat. Taking the first reason,

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TABLE SHOWING RESISTANCE AND CURRENT-CARRYING CAPACITY OF WIRES OF DIFFERENT MATERIALS AND GAUGES.

B.W.G.	Galvanised Iron.		German Silver.		Platinoid.		Manganin.	
	Ohms per yard.	Amperes.	Ohms per yard.	Amperes.	Ohms per yard.	Amperes.	Ohms per yard.	Amperes.
8	0·008	28·0	0·017	19·0	0·024	13·5	0·028	13·5
9	0·010	23 0	0·022	15·0	0·028	11·0	0·036	11·0
10	0·011	21·0	0·025	14·0	0·037	10·0	0 040	10·0
11	0·014	18·5	0·030	12·5	0·043	9·0	0·048	9·0
12	0·018	16·0	0·038	11·0	0·057	7·7	0·063	7·7
13	0 025	12·5	0·052	8·5	0·068	6·0	0·084	6·0
14	0·035	10·0	0·061	7 0	0·096	4.7	0·109	4·7
15	0·041	8·0	0·082	5·5	0·119	4·0	0·146	4·0
16	0·048	7·5	0·100	5·0	0·150	3·5	0·166	3·5
17	0·062	5·7	0·124	4·0	0·187	2·7	0·218	2·7
18	0·087	4·5	0·175	3·0	0·267	2·2	0·304	2·2
19	0·118	3·7	0·241	2·5	0·350	1·7	0·415	1·7
20	0·123	3·5	0·345	2·2	0·475	1·5	0 434	1·5
21	0·204	2·5	0·410	1·7	0·603	1·2	0·715	1·2
22	0·266	2·0	0·539	1·5	0·785	0·95	0·934	0·95
23	0·335	1·7	0·675	1·2	0·987	0·8	1·200	0·8
24	0·431	1·5	0·871	1·0	1·270	0·7	1·500	0·7

a No. 20 wire made up into a spiral of $\frac{7}{8}$ in. internal diameter and of an ordinary length would never do, as such a coil would be weak and unstable. If placed vertically it would close up at the bottom; and if placed horizontally it would sag. The antithesis would be a No. 8 wire coiled up to $\frac{1}{2}$ in. internal diameter. This would be practically impossible to achieve. On the other hand, it would be possible to coil a No. 20 wire up to a diameter of $\frac{7}{8}$ in. and make it stable by pulling out; but this obviously reduces its efficiency per foot of spiral, which is important where space is a consideration, although it would increase its efficiency as a heat radiator almost to a maximum. What is required, therefore, is to find the point where rigidity, heat radiation, and energy dissipation per unit of spiral length are concurrently at their maxima. This has been ascertained experimentally, and is given below in tabulated form for various gauges:—

DIMENSIONS OF SPIRALS FOR DIFFERENT GAUGES.

B. W. G.	Internal diameter of Spiral.	Approximate length of Spiral.
Up to No. 8,	1 inch	27 inches
9, 10, 11,	$\frac{7}{8}$,,	22 ,,
12, 13, 14,	$\frac{3}{4}$,,	18 ,,
15, 16,	$\frac{5}{8}$,,	14 ,,
17, 18, 19,	$\frac{1}{2}$,,	21 ,,
20 to 24	$\frac{3}{8}$,,	8 ,,

The dimensions given are based upon the pitch of the coils being equal to twice the diameter of the wire, excepting in the smallest sizes, where it is expedient to increase the pitch slightly. They are, of course, approximate, and need not be rigidly adhered to.

In practice it is usual to standardise these spirals; that is to say, a certain gauge of wire suitable for the current proposed, and of a known resistance per unit of length, wound into coils of a certain diameter and pitch, will dissipate a known quantity of energy per foot of spiral. It follows, therefore, that when the requirements as to resistance and carrying capacity are known, it is only necessary to specify so many feet of such and such a spiral. When such information is not at hand, it may be easily worked out, the pitch and diameter of the coils being arranged as above. The results may not be absolutely accurate owing to irregularities in the wire, but they will be near enough.

In starting a shunt-wound motor, the field magnet circuit should first be connected directly across the supply mains. This ensures a strong field in the air gap, with the result that a comparatively small current is required to produce the necessary torque or turning moment. The armature is then connected across the mains through a resistance of such magnitude that the initial current shall not be excessive. This resistance is progressively decreased as the motor speeds

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up and generates a higher and higher back E.M.F., until at last the whole of the resistance is cut out, the armature, like the field magnets, being connected directly across the mains.

A motor starter, if efficiently designed, should also fulfil several other conditions. When the motor is being switched off, the full supply voltage is maintained across the field magnet circuit up to the last instant. If the magnet circuit is then suddenly broken, the sudden stoppage of the current, combined with the self-induction in the circuit, produces a high E.M.F., which may injure the insulation of the magnet windings. Accordingly on switching the motor out of circuit, the field magnet windings should be left in series with the armature, so that the field current can die down gradually.

Further, as continuity of supply can never be absolutely assured, it becomes necessary to provide all starting switches with some arrangement whereby, in the event of the supply failing, the circuit of the motor is automatically opened. If this were not done, the mains would obviously be short-circuited by the stationary motor when the supply was resumed.

It is also convenient, in most cases, to provide another automatic arrangement that will open the circuit on the occurrence of an overload which would entail an armature current sufficient in magnitude to damage the windings.

Fig. 1 represents the connections of a British Thomson-Houston shunt-wound motor starting resistance, fitted with "no voltage" and "overload" release. In the position of the switch shown, as all the starting resistance is cut out, the motor is running at full speed, and the current is flowing through the + fuse and switch to the motor, after leaving which it passes through a terminal to the last contact of the resistance. Thence it flows through the switch arm, round an electro-magnet M_1 wound with a few coils of thick wire and fitted with a hinged keeper, and so through another terminal to the return lead.

The field magnet current starts at the + brush of the motor, goes round the fields, through the coil of another electro-magnet M_2, and so to the first stop of the resistance.

As will be noticed, the ends of the coil of M_2 are also connected to two stops placed just over the hinged keeper of M_1, the end of which is fitted with a copper bridge piece.

Fixed to the switch arm is a piece of iron which acts as keeper to the shunt magnet M_2. So long as there is sufficient current in the fields of the motor, the arm is kept in the above position against the pull of a powerful spring, the presence of which, for the sake of simplicity, is only indicated.

Now in the event of the field current failing (say through a break in the field winding or total interruption of supply), the electro-magnet through which it passes loses its power, and the arm is sharply drawn by the spring across the contacts to the "off" position, thus preventing the dead short circuit that would occur at once in the former case, and upon resumption of supply in the latter.

In a somewhat similar manner, should the current in the motor armature increase abnormally (say through the machinery it is driving becoming jammed), the keeper of M_1 is drawn up, and its contact bridges the two stops just above it, and so short circuits the shunt coil M_2, which again, losing its power, allows the switch arm to break circuit, be it noted, through the resistance, so that the spark on the last contact will be small and not destructive. The value of the overload current at which this coil acts can be varied by means of a screw which raises or lowers the keeper, and so makes the device more or less sensitive. Large sizes are fitted with a magnetic blow-out arrangement which prevents arcing as the switch is moved off the last stud.

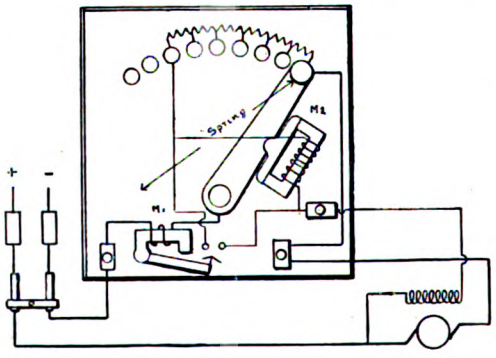

FIG. 1.

The above connections show that, on starting, the field is fully excited directly the switch touches the first contact. In some makes this is specially provided for by the addition of a small stud connected to the shunt, which the arm touches before it puts the armature in circuit. Upon stopping, it will be seen if the connections are followed out, that the field circuit is not abruptly

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broken, but is left connected in series with the coil of M_1, the starting resistance, and the armature of the motor.

This example is typical of the best modern construction; but an overload release is not always fitted, especially in large sizes, many experts preferring a separate circuit breaker, which is a more expensive but perhaps more thorough arrangement.

The switch arm should be provided with a laminated contact, in order to ensure uniform pressure on the studs. The area of a stud should be such that the current density does not exceed about 190 amperes per square inch.

We now come to a most important point—*viz.*, the correct proportion in which the resistance of a starter should be divided up. It is quite impossible to lay down any general rule on this point, as for maximum efficiency every motor should have its starter designed for it, taking into account the nature of the work it is to perform, and therefore the conditions under which it is to be used. The starting conditions may be classified as follows: (1) No load, (2) light load increasing with speed, (3) steady full load with little or no inertia, (4) full load with great inertia. Obviously, one and the same starting switch will not act well under all the above conditions. If designed for the first, it would probably be burnt out under the last; and if *vice versâ*, the number of steps, and consequently the cost, would be unnecessarily great. Practice, therefore, tends to average conditions, and thus produce a stock resistance that in ordinary sizes will take about full load current on the first step in order to make sure of a start. Equally as important as the number of steps is the proportion that the resistances of succeeding sections bear to one another. In the early days it was customary to divide a starter up into a number of sections of equal resistance, care only being taken that, when the switch is moved over to the first stud, the whole of the resistance being then in the armature circuit, the momentary current should not be very much over that taken at full load. The momentary current, on touching the succeeding studs, was not troubled about, and often considerably exceeded this value. It is instructive to take an example of this old style of design, following it through, step by step, and noting the results as each succeeding stud is touched by the switch.

Let us suppose that the resistance is to be used to start a 10-h.p. shunt-wound motor. Let the current be supplied from 200 volt constant pressure mains. Then, if c is the current required to drive the motor at full load, we have

$$10\text{-h.p.} = 7460 \text{ watts},$$
$$\therefore\ cE = 7460,$$
$$c = \frac{7460}{200} = 37{\cdot}3 \text{ amperes.}$$

In starting a shunt-wound motor, the resistance is included in the armature circuit, the field magnet circuit being connected directly across the supply mains. Thus the field in the air gap is approximately constant, and therefore the torque on the armature will be directly proportional to the armature current. Let us suppose that the resisting torque due to the load on the motor is constant; this will generally be the case when the motor is used to drive machinery. Then shifting the switch from one stop to the next will momentarily increase the armature current, thus producing an augmented torque. As a consequence, the speed of the motor will increase, thus producing an increased back E.M.F., and so diminishing the current. This action will continue until the current falls to the value necessary for overcoming the constant resisting torque, after which the speed and the current will remain constant so long as no further alteration is made in the starting resistance.

Let us suppose that the motor is to be started when partially loaded, the current required to produce the necessary torque being 10 amperes. Let the armature resistance, from brush to brush, be $0{\cdot}2\ \omega$; while the starter has a total resistance of $5{\cdot}4\ \omega$, divided into three equal sections of $1{\cdot}8\ \omega$ each.

On bringing the switch to the first contact stud, the total resistance in the circuit will be $5{\cdot}4 + 0{\cdot}2 = 5{\cdot}6\ \omega$. Since the motor is initially at rest, there will at first be no back E.M.F., so that the current C will momentarily rise to the value

$$C = \frac{200}{5{\cdot}6} = 35{\cdot}7 \text{ amperes.}$$

The consequent torque will more than suffice to overcome the resisting torque, so that the armature commences to rotate at an increasing speed. The speed becomes constant when the back E.M.F. rises to a value sufficient to reduce the current to 10 amperes. In this case,

Voltage of supply = ohmic drop in armature and starter + Back E.M.F. . . (1)

$$\therefore \text{ Back E.M.F.} = 200 - 10 \times 5{\cdot}6 = 144 \text{ volts.}$$

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On moving the switch over to the second contact stud, the resistance in the armature circuit is reduced to 3·8 ω. Until the motor has had time to appreciably alter its speed, the back E.M.F. will be sensibly equal to 144 volts; and in these circumstances, equation (1) shows that the momentary current C will be determined by the equation

$$C \times 3{\cdot}8 = 200 - 144 = 56;$$

$$\therefore \quad C = \frac{56}{3{\cdot}8} = 14{\cdot}7 \text{ amperes.}$$

As before, the speed of the motor increases until the current falls to 10 amperes. In these circumstances, equation (1) shows that

Back E.M.F. = $200 - 10 \times 3{\cdot}8 = 162$ volts.

On moving the switch over to the third contact stud, the resistance in the armature circuit is reduced to $1{\cdot}8 + 0{\cdot}2 = 2$ ohms. The momentary value, C, of the current, according to (1), is given by the equation

$$C \times 2 = 200 - 162 = 38;$$

$$\therefore C = 19 \text{ amperes.}$$

The speed once more increases until the current falls to 10 amperes, when

Back E.M.F. = $200 - 10 \times 2 = 180$ volts.

On moving the switch over to the fourth and last contact, the resistance in the armature circuit is reduced to 0·2 ohms. The momentary value, C, of the current is given by the equation

$$C \times 0{\cdot}2 = 200 - 180 = 20;$$

$$\therefore C = 100 \text{ amperes.}$$

The faults of the starting resistance just described are obvious. The momentary currents at the first and fourth stops are excessive: especially in the case of the fourth stop. Such heavy currents would tend to injure the armature insulation by an excessive production of heat; as well as producing a sudden and violent increase of torque, which would be mechanically injurious.

The above values of the momentary currents on shifting the switch would not be actually reached in practice, since an armature possesses considerable self-induction, and the effect of this is to delay the increase or decrease of a current. Nevertheless, the above calculation shows that the design described is but ill adapted to the purpose of a motor starter.

It is possible to design a motor starter so that the momentary increase of current, produced by shifting the switch from any one stud to the next, shall have a constant value. The following will explain how this can be effected:—

Let r = armature resistance, from brush to brush, *i.e.*, total resistance in armature circuit when switch is on last stud.

Let R_1 = total resistance in armature circuit when switch is on last stud but one.

Let R_2 = total resistance in armature circuit when switch is on last stud but two.

. . . . = ...

Let R_n = total resistance in circuit when switch is on first stud.

Let c = current required to produce necessary torque in motor.

Let C = maximum permissible value of current.

Let E = voltage of supply;

Then, when the switch has been for some time on last stud but one,

$$\text{Back E.M.F.} = E - c R_1$$

When the switch is moved over to the last stud, the starting resistance is entirely cut out, and the only resistance left in the armature circuit is that of its own conductors. Then to determine the momentary current C, we have from (1)

$$C r = E - (E - c R_1) = c R_1;$$

$$\therefore R_1 = \frac{C}{c} r \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Going back to the time when the switch had been for some time on the last stud but two,

$$\text{Back E.M.F.} = E - c R_2$$

On moving the switch over to the last stud but one,

$$C R_1 = E - (E - c R_2) = c R_2;$$

$$\therefore R_2 = \frac{C}{c} R_1 = \left(\frac{C}{c}\right)^2 r \quad . \quad . \quad . \quad (3)$$

$$\text{Similarly, } R_3 = \left(\frac{C}{c}\right)^3 r, \text{ etc.}$$

Thus the resistances r, R_1, R_2, R_3, etc., form a geometrical progression, any term being found by multiplying the preceding term by $\frac{C}{c}$ (*i.e.*, the ratio of the maximum permissible current to the normal working current).

If the motor is required to start when the switch is moved over to the first contact, then

$$\frac{E}{R_n} > c; \quad \therefore R_n < \frac{E}{c} \quad . \quad . \quad . \quad . \quad (4)$$

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As an example of the application of this method, let us suppose that the starting resistance already criticised is to be replaced by one in which the current never acquires a momentary value greater than 20 amperes.

Then $C = 20$, while $c = 10$; $\therefore \frac{C}{c} = 2$.

$r = 0{\cdot}2$; $\therefore R_1 = \frac{C}{c} r = 2 \times r = 0{\cdot}4\ \omega$.

$$R_2 = \left(\frac{C}{c}\right) R_1 = 2 \times 0{\cdot}4 = 0{\cdot}8\ \omega.$$

$$R_3 = \frac{C}{c} R_2 = 2 \times 0{\cdot}8 = 1{\cdot}6\ \omega.$$

$R_4 = 2 \times 1{\cdot}6 = 3{\cdot}2\ \omega$.
$R_5 = 2 \times 3{\cdot}2 = 6{\cdot}4\ \omega$.
$R_6 = 2 \times 6{\cdot}4 = 12{\cdot}8\ \omega$.

For the motor to start when the switch is moved on to the first stop, the total resistance in circuit at that moment must be less than

$$\frac{200}{10} = 20\ \omega.$$

Thus, if we arrange that the total resistance of the starter is equal to $12{\cdot}8 - 0{\cdot}2 = 12{\cdot}6\ \omega$, the motor will start when the switch is moved on to the first stop, the momentary current being equal to

$$\frac{200}{12{\cdot}8} = 15{\cdot}6 \text{ amperes.}$$

At each succeeding stud the maximum momentary value of the current is equal to 20 amperes, thus corresponding to a momentary rise of 10 amperes.

The total resistance of the starter must be subdivided as follows :—

Between.	Resistance.
1st and 2nd stud . .	$12{\cdot}8 - 6{\cdot}4 = 6{\cdot}4\ \omega$.
2nd „ 3rd „ . .	$6{\cdot}4 - 3{\cdot}2 = 3{\cdot}2\ \omega$.
3rd „ 4th „ . .	$3{\cdot}2 - 1{\cdot}6 = 1{\cdot}6\ \omega$.
4th „ 5th „ . .	$1{\cdot}6 - 0{\cdot}8 = 0{\cdot}8\ \omega$.
5th „ 6th „ . .	$0{\cdot}8 - 0{\cdot}4 = 0{\cdot}4\ \omega$.
6th „ 7th „ . .	$0{\cdot}4 - 0{\cdot}2 = 0{\cdot}2\ \omega$.

This aspect of the subject is very little understood, as is exemplified by the widely varying, and sometimes absurd, rules imposed by different supply companies. On the whole, their wishes may be interpreted in this manner :—They do not object to a motor taking a large current, provided this is put on gently, step by step. If these requirements are followed, the resistance may have to be designed so that the motor will not start until the first few steps are passed over, the use of these steps being simply to make it impossible to apply the full load current at once, and so cause a bad drop of pressure.

From the practical point of view, about the most reasonable rule appears to be this :—For motors taking somewhere about 50 amperes on full load, momentary increase on first and all successive studs, 10 amperes. For much smaller motors half full load current on first stud, and a quarter on every other, provided none of these exceeds 10 amperes. If the current exceeds 50 amperes on full load, the momentary increase of current should not be greater than one-fifth of the full load current on first and all succeeding studs.

The division of a starting resistance must, of course, always be carried out with due regard to the voltage between neighbouring studs: arrangements should be made to preclude the possibility of there ever being a P.D. between neighbouring studs sufficient to set up an arc when moving the switch arm either forward or back.

To illustrate this point, let us consider the action of the resistance just designed, especially when it is being used to stop a motor. When the switch has been on the second stud for a short time, the current will acquire the value of 10 amperes. On moving the switch over to the first stud, an extra resistance of $6{\cdot}4\omega$ is included in the circuit; and when the current has again reached its normal value, there will be a P.D. of $6{\cdot}4 \times 10 = 64$ volts between the first and second studs. Now shifting the switch from the second to the first stud is likely to produce a spark, and experience shows that when the normal P.D. between the studs exceeds about 35 volts, the spark starts a permanent arc which speedily eats the studs away.

To avoid arcing, it is clear that the resistance of a section must be such that the P.D. across its terminals, when the working current is flowing, shall not exceed 35 volts. Thus, the resistance just designed should be modified so that no section has a resistance exceeding $3{\cdot}5\ \omega$, which can be arranged by dividing the section with a resistance of $6{\cdot}4\omega$ into two equal parts, with separate contact studs. Thus, in designing a starting resistance, we may proceed as follows :—

(1) Let $\frac{C}{c} = k$. Thus the value of k becomes known when the permissible momentary increase of current is given.

As proved on p. 472, the total resistance in the armature circuit, when the switch makes contact with the last stud but one, must be equal to $k\,r$. Thus the resistance between the last two studs must be equal to

$$k\,r - r = (k - 1)\,r.$$

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When the switch is on the last stud but two, the total resistance in the armature circuit must be equal to $k^2 r$; therefore the resistance between the studs must be equal to

$$k^2 r - k r = (k - 1) k r.$$

Similarly the resistances between succeeding pairs of studs must be

$$(k-1)k^2r,$$
$$(k-1)k^3r, \quad (k-1)k^4r,$$
etc., etc.

(2) In following out the above process, when we come to a section of which the calculated resistance is found to be such that the normal working current would produce a P.D. of more than 35 volts between its terminals, then the above process must be discontinued, the resistance of this and the remaining sections being made equal, and of such a value that the P.D. between the terminals of each shall be less than 35 volts.

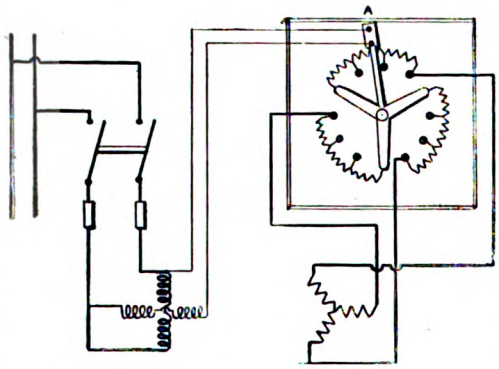

FIG. 2.

(3) If the motor is required to start when the switch is on the first stud, the total resistance then in the armature circuit must be less than E/c, as shown by equation (4), p. 472.

If the momentary increase of current is limited to a certain value c^1, then the momentary current flowing through the armature when the switch is moved on to the first stud must not exceed this value, so that if R_n is the total resistance in the armature circuit for that position of the switch,

$$R_n > \frac{E}{c^1}$$

It may not be out of place to shortly consider the connections of an alternating current motor starter, taking, for example, the well-known Heyland single-phase motor, manufactured by Messrs. Witting and Eborall. According to the conditions under which it is to work, it is supplied with gear for starting either with full or no load torque.

Roughly, the principle of the motor is as follows:—The stator is arranged with two slot-wound drum windings: one, the running winding, is always in circuit; and the other, the starting winding, only temporarily so, its function being to provide a cross magnetic field that acts on the rotor currents and produces the starting torque. These windings are shown in Fig. 2 respectively thick and thin, the connections being those for starting with full load torque.

The rotor is wound in slots with three separate drum-wound coils connected together at the centre, as shown.

The other ends are taken to three slip rings, and thence through brushes to their respective contacts on the starting switch.

In the position shown, the motor is just starting, the auxiliary switch A, which moves with the three-forked main switch, having closed the circuit of the auxiliary coil. When up to at least half speed the switch is moved on to the next contact, cutting out the auxiliary coil and also part of the resistance in the rotor circuit. On the final stop the rotor is short-circuited. In order to economise current it is always desirable to cut out the starting coil as soon as possible; but as mentioned, this must not be done until the motor has attained a fair speed.

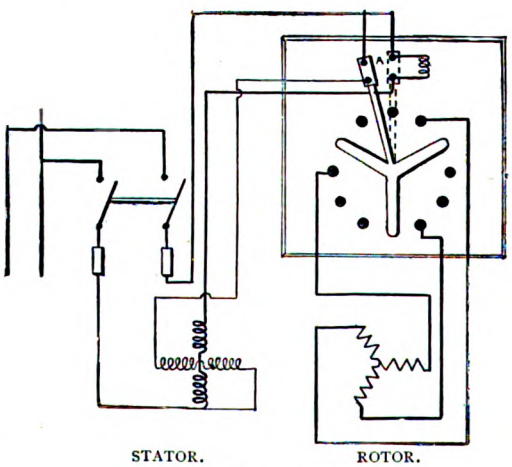

FIG. 3.

In stopping, the main switch is first opened, and the starter then rotated backwards to the "off" position.

In the above case (*viz.*, starting with full load torque) the initial current for periodicities up to 60 per second is twice the full load current, and over this and up to 100 it is

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about 50 per cent. greater; but in starting under no load, it may be taken as four-fifths of the full load current over the first range of periodicities, and full load over the rest.

The connections in this case are somewhat different (*see* Fig. 3), a resistance being inserted in the running coil circuit, in order to keep down the unnecessarily large starting current as much as possible. The auxiliary switch short-circuits this on the third contact, as shown, directly after it has cut out the starting coil.

For polyphase motors the same sort of starter is used, *viz.*, a set of resistances in the rotor circuits; but as auxiliary coils are, of course, not necessary, the auxiliary switch is dispensed with.

COTTON SPINNING.

How to set the Rollers in Cotton Machinery.

By WM. SCOTT TAGGART, M.I.Mech.E., Author of "Cotton Spinning."

COTTON SPINNING is essentially a practical process, or rather a series of various practical processes. It has its theoretical side, and one can with reason speak of the "Theory of Spinning," and even more so, describe the processes under such a heading as the "Science of Spinning." This would be correct, simply because the different processes, and the mechanism by which they are performed, are based on principles, a knowledge of which all well-informed workers ought to possess. Beyond this, however, the working of the raw material into a successful yarn belongs to a very practical department of work, and pure theory will never make anyone a spinner, though it will assist, to a considerable extent, in enabling a practical man to make great advances in his work.

The character of the material is such that mathematical exactness will never be attained, even remotely comparable to the exactness attained in many other purely mechanical operations. For instance, wire may be drawn out to any degree of fineness, and a guarantee given that it is practically exact throughout its length: it may even be spun into an almost perfect thread. In the same way, the reproduction of parts of machinery by machine tools, such as planing machines, shaping machines, milling machines, lathes, etc., can be done to such perfection that variations represent the minimum of error from exactness or the desired result. In this connection one hears such machine parts described as being mathematically correct; a description of this kind can never be applied to cotton spinning as a process. A practical mind and practical supervision are absolutely necessary in managing the raw material, as distinct from the practical attention to the purely mechanical actions of the machinery employed.

Along with several other factors, "averages" form a very important feature to the spinner in his management of the cotton fibre, from the first machine in the mill to the last.

In the first place, he depends upon the average length of the fibres or staple; he often purchases it directly on this basis, and in all other cases indirectly. A cotton that has a good average, *i.e.*, a cotton whose fibres in general have a minimum of variation from the average, is a good cotton. It may be pointed out that the average length of cotton is not the average struck

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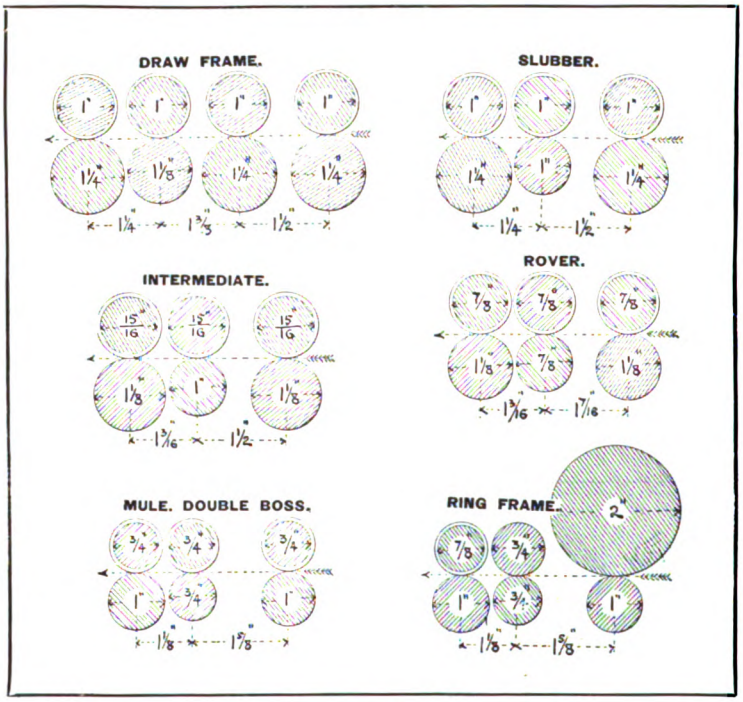
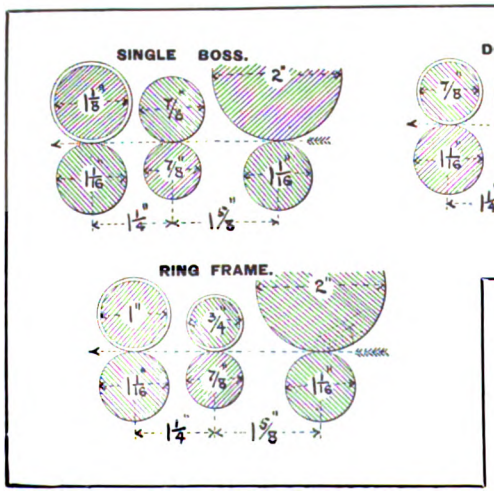
between the longest and shortest fibres in any given class: for instance, suppose in a set of ten fibres the longest is $1\frac{1}{4}$ inches and the shortest 1 inch, the average of these two of $1\frac{1}{4}$ inches, one of $1\frac{1}{8}$ inches and two of 1 inch, such a combination would give an average of 1·187 inches. Now, these differences in averages must be seriously taken



American Cotton.

extremes would be $1\frac{1}{8}$ inches; of the ten fibres, however, there may be one of $1\frac{1}{4}$ inches, two of $1\frac{1}{8}$ inches, and seven of 1 inch, the average in this case would be 1·05 inches. On the other hand, there may be seven fibres into account if the resulting yarn is to be considered good.

Again, the law of averages is a great factor in all processes of doubling cotton, whether at the scutcher, in the card room, or on the spinning and doubling machines.



This question alone calls into being a high degree of skill and judgment, much of which can only be acquired by experience. Unfortunately, men who have attained responsible positions in the textile industry are very reluctant to impart information as to their methods of attaining certain results, so their experience is very seldom placed within reach of students.

The question of averages becomes of great importance, and indeed, is vital to success, when we come to consider it in relation to

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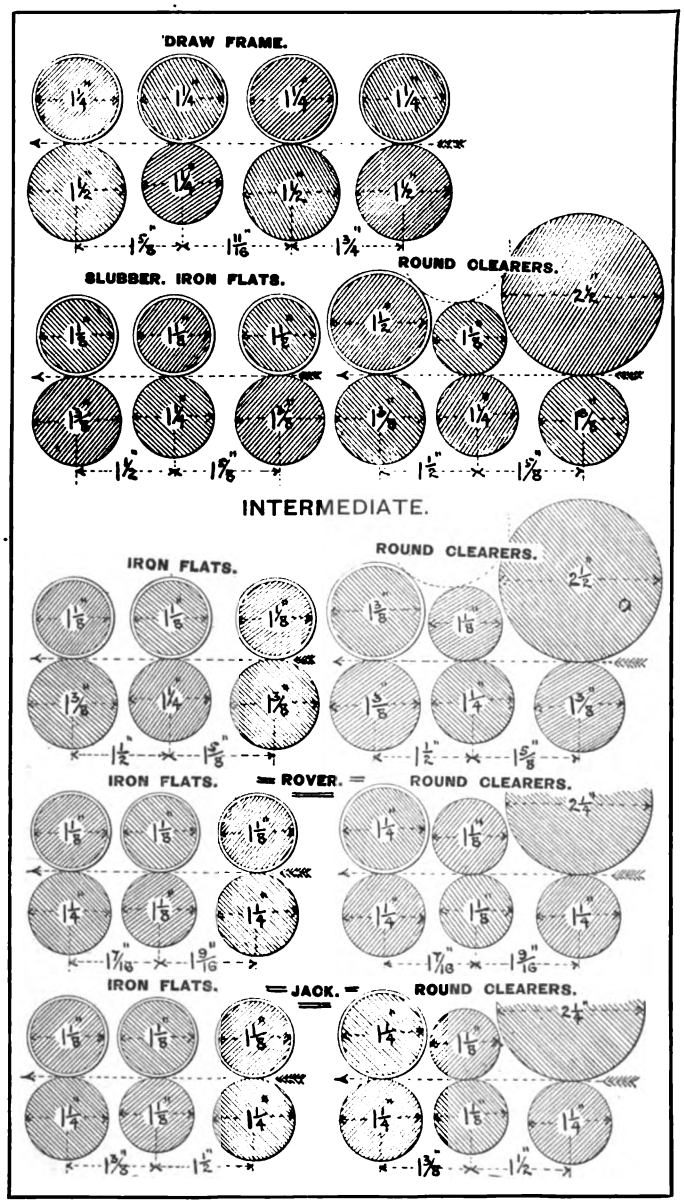
the setting of the rollers in the various machines through which the cotton passes. The series of drawings here given, present in a concise form a vast amount of useful information to the student. The setting of the rollers is one of those matters that depends, to a large extent, upon experience and trained judgment. Slight differences between the centres of the different lines of rollers will produce differences of quality in the resultant roving or yarn.

In deciding such matters, the following factors must be carefully noted: Are the fibres fairly regular in length? the amount of cotton passing between the rollers: the speed of various lines of rollers: the draft between the various lines of rollers; and the weight pressing on the rollers.

All these factors have some value, and whilst the drawings present a good general average of results taken from actual working conditions, it must be understood that the variable character of cotton from time to time, necessitates alterations in the dimensions given. They will enable the student, at least, to gain some fundamental knowledge early in his career, that will teach him to overcome one of the important and even difficult features of successful cotton spinning.



EGYPTIAN COTTON.

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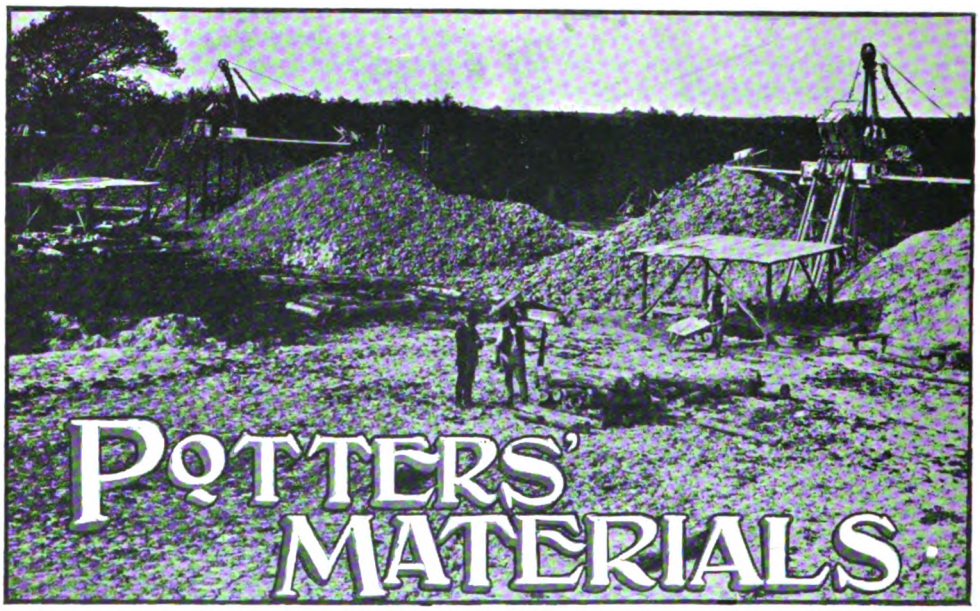

POTTERS' MATERIALS.

By **WILTON P. RIX, late Manager of Doulton's Lambeth Art Pottery.**

FOR pottery purposes it is customary to include under the general term *clay*, all materials which become plastic when mixed with water, and which, after firing, remain coherent.

The ingredient which gives clay its plasticity, is invariably hydrosilicate of alumina. Many other non-plastic ingredients, however, are usually present, and the qualities of the clay are more or less influenced thereby.

The geologist is accustomed to distinguish types of clay chiefly by the main features of their construction, or their positions in relation to other deposits. On the other hand, the clay-worker is accustomed to have regard more especially to the physical composition of the mass as it comes to hand. It is on the variation in this physical condition, as much as to the proportion and nature of foreign ingredients, that his success or failure depends. It may often happen, through some apparently slight variation in one of these factors, that one deposit may be altogether inferior in value to another immediately adjacent and apparently similar.

Primarily, the presence of a high proportion of hydrated bisilicate of alumina (Al_2O_3, $2SiO_2$, $2H_2O$)* is regarded as giving value to a clay substance. This element gives plasticity, while other constituents add other properties equally necessary for certain conditions of clay working.

It is on these other constituents, their proportion and their nature, that the suitability of the clay mass for any particular branch of work depends. In some cases the addition or removal of certain ingredients may adapt the clay for other purposes, but as a rule it is more economical to avoid such a course.

Pure clay has the following composition, the proportions being taken by weight :—

Alumina	. .	39·77 per cent.
Silica	. .	46·33 ,,
Water	. .	13·90 ,,
		100·00

This represents 2 atoms of silica, 1 atom of alumina, and 2 atoms of water, which are in chemical combination. In addition to the combined water stated above, moisture is absorbed from the atmosphere to the extent of 3 per cent. to 8 or 9 per cent., according to physical condition.

Pure clay, however, never exists in nature in its free state, being always mixed with foreign ingredients.

The first influence of the application of increasing heat to clay is to dispel the

*This formula is now usually adopted by ceramic chemists, though some, including Bischoff, Salvetat and others, give the formula for pure clay as $2Al_2O_3$, $3SiO_2$, $4H_2O$. To this latter Seger does not agree.

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moisture which accumulates in the pores of the material, being taken up from the atmosphere. The amount of this moisture varies with the state of the atmosphere and the texture of the clay.

When a temperature of about 100 C. is reached, the moisture which has been thus mechanically mixed with the clay substance is entirely evaporated. Above this temperature the 2 atoms of combined water present in the clay are gradually dissociated, until at about 400 C. the hydrated silicate of alumina becomes partially decomposed. The action continues until it is completed at about 650 C., leaving as the residue a mixture of silica and alumina in the ratio of 53·81 per cent. of the former to 46·19 per cent. of the latter. With the expulsion of this combined water the plastic properties of the clay disappear, nor can the clay be again brought into the plastic condition.

It will be found that a further increase of temperature produces a fresh change of condition, the silica and alumina entering into new combination, forming together a silicate of alumina which is *anhydrous*. This change is, as a rule, complete between 1150° C. and 1200° C.

No influence is exerted by dilute acids on clay in the raw state. Sulphuric acid, however, when concentrated, decomposes the silicate when heated to 300° C. Hydrochloric acid has a similar effect under the same conditions, and both act upon the anhydrous silicates in the same way if the operation is prolonged.

Soda and potash when admixed with the clay, either in solution or in the solid state, will combine with the hydrosilicate of alumina, and thus form a double silicate, if fired for a considerable length of time. This reaction, however, does not take place in the case of *anhydrous* silicates of alumina.

Physical Characteristics.

The essential and cardinal properties of clays, on which their value for ceramic purposes depends, are *plasticity* under the influence of added water, and *hardening* under the influence of heat. The amount of water requisite to obtain the greatest degree of plasticity varies with the amount and condition of *non-plastic foreign material* present in its mass. The amount of heat required to harden it depends upon the amount of *fusible foreign ingredients* present in its mass.

With an increasing amount of water, the plasticity of a clay gradually increases up to a certain point. Beyond this point, however, a further addition of water decreases the plasticity, until the latter is finally lost when the mixture assumes the liquid state.

As already pointed out, the limit of *plastic saturation* varies with clays of differing composition. The amount of water required becomes less in proportion to the increase in size and quantity of the non-plastic particles contained in the clay mass. This added water acts upon the clay, partly as an agglomerative, binding the particles together; while it also acts as a kind of lubricant between the clay particles, allowing these to move freely one over another while the clay is being given any required shape.

It also follows that, as the addition of water causes a separation of the clay particles, so that they can move freely, and thus gives plasticity to the mass, so the further and excessive addition of water will cause the clay particles to be placed at such distances one from another that they no longer touch, but merely circulate in the liquid, and plasticity therefore ceases.

Other liquids besides water can be used to obtain plasticity, such as vegetable oils or syrup. Turpentine and alcohol, however, have no effect; while glycerine tends to destroy plasticity when mixed with clay in a plastic state.

The property of becoming plastic is not, however, peculiar to clay, though it is far more marked than in any other mineral substance. The cause of this plasticity was long disputed, but is now considered to be chiefly due to two causes:—

(*a*) The extreme fineness of the clay particles.

(*b*) The laminated form of the particles themselves, which allows of closer contact and increased attraction.

If plastic clay is left in an atmosphere containing little or no moisture, the water gradually evaporates. During this process the surface water is first removed, and the moisture from within gradually rises to the surface to fill the pores left vacant. This moisture is in turn removed, and finally the whole mass becomes dry.

The effect of the first stages of drying is to bring the clay particles into contact as the water leaves the pores, and this causes a *shrinkage* of the mass in proportion to the volume of water removed. When all the clay particles are in close contact shrinkage ceases, and the intervening pores become vacant as the remaining moisture is completely discharged. At the same time the mass hardens and is physically changed in character. The density and cohesive strength

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of the mass is very apparent, the molecules being drawn much more closely together during the shrinkage.

The importance of this change may be sufficiently appreciated by comparing the behaviour of clays under these conditions with that of other substances. If, for instance, a small quantity of very fine wet sand or mica be formed into a mass, as previously described, a certain amount of plasticity may be obtained, enabling the material to be put into form; but the whole falls back into a powder when dry, instead of retaining its shape, as in the case of clay. On this peculiar property, therefore, rests the fundamental value of clay as an industrial requisite.

Kaolin (or China Clay).

It has already been stated that *pure* clay does not exist in nature. Kaolin is, however, the mineral which approaches most nearly to that material. It is white or pale grey in colour, having considerable plasticity, though less so than ball clay, owing to the particles being less minute. It is also more or less mingled with small quantities of other mineral substances, and these cause variations in its useful properties, so that for the highest quality of ware they require to be removed.

Structurally, kaolin differs somewhat from ball clay, being made up of particles differing considerably in physical characteristics. Examination under the microscope reveals the fact that the particles are relatively much larger than those of ball clay: some are six-sided, crystalline scales or plates, while others are apparently amorphous, opaque, and of the nature of mud-particles; moreover, some amount of extremely fine quartz crystals are generally present. All these constituents modify the working properties of kaolin, according to their proportion in the mass.

Chemically, the average composition of kaolin shows a lower content of silica and iron than ball clay, and more usually of alkalies. This will be seen by comparison of the following analyses:—

	Ball Clay.	Kaolin, or China Clay.
Silica . . .	52·06	47·96
Alumina . .	29·38	38·29
Iron Oxide . .	2·37	0·90
Lime . . .	0·43	0·43
Alkalies . . .	2·29	0·56
Water . . .	12·70	12·76

While the analyses here given represent an average quality, it is necessary to point out that deposits vary considerably. Thus, some are more *siliceous*, containing as much as 64 per cent. of silica. Others are more *alkaline* in composition, due to the presence of a large proportion of felspathic particles in the mass. The amount of alkalies may thus rise to 4 per cent., or even 5 per cent., as in the case of some Chinese kaolins.

The contents of *iron oxide* should not rise to more than 1 per cent., and even this amount gives a distinctly yellowish tint to the ware; in the whitest kaolins the percentage falls so low as 0·42, as in the case of some of those found in Japan.

Kaolins are far more unctuous to the touch than ball clays, and emit a characteristic earthy smell when breathed upon. As a rule they are refractory, though they become fusible when iron oxide and lime are *both* present in large quantities.

Sources of Clay Material.

It will be noted, from what has been said, that the qualities of ball clays and kaolins vary greatly one from another: not only in composition, but also in physical structure. The reason for this divergence may be traced to the differing sources from which they are derived, and it may therefore be well to glance at the conditions under which the formation of each has taken place.

Clay material is the result of two processes in nature, *disintegration* and *attrition*. In some instances we find certain rocks, such as granite, porphyry and gneiss, partially decomposed, under exposure to climatic action, so that, embedded in the mass, there are parts which have changed their condition from rocky to clayey consistency. This is partly due to change of chemical composition, and partly to change of physical condition caused by the atmosphere.

Under such disintegration ordinary kaolin or China clay is produced. The material, however, can rarely be used in its natural state, being usually entangled with rocky débris from which it must be removed by washing, to be afterwards deposited as a sediment, and dried in the form of China clay with which the potter is familiar.

Ball clays afford an example of the action of *attrition*. In this case the washing process has been carried out by natural instead of artificial means. Besides this, they have undergone natural attrition through the action of rushing water, by which the detached particles have been carried along. If the water which has dis-

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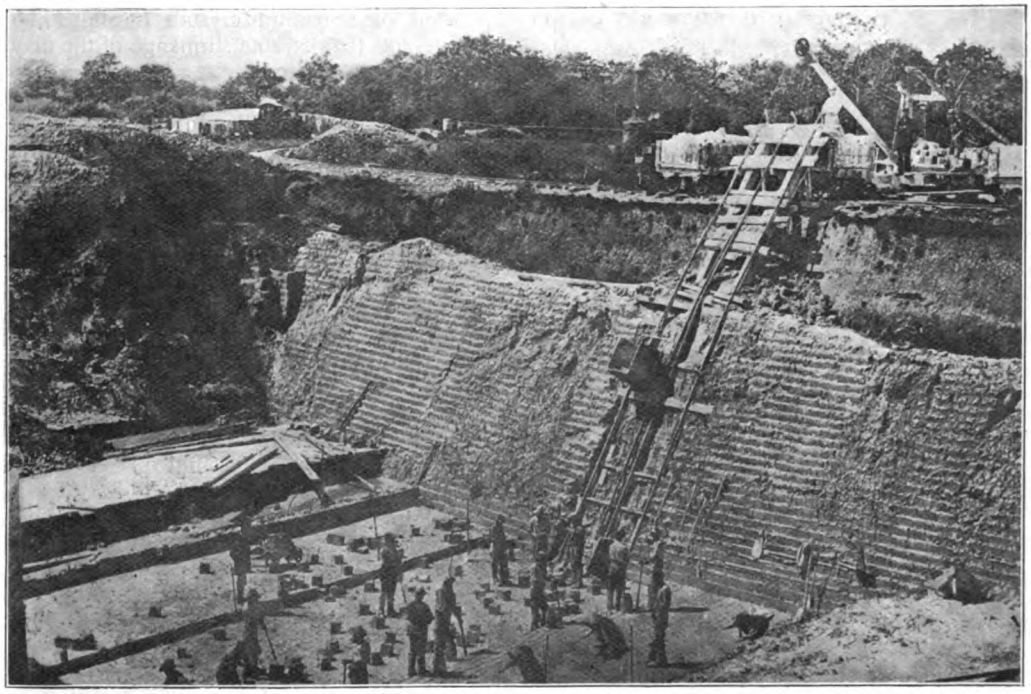
placed the particles maintains its rapid motion for only a short distance, the clay substance will be deposited as the speed decreases: the heavier and larger particles first, the finer clay being kept longer in suspension, so that the lower layers will be more sandy, and the upper layers more unctuous.

If, however, the rush of water continues to greater distances, two results occur. The clay and sand particles carried along suffer attrition, and these become finer in consequence; while at the same time a greater amount of impurities are taken up from the bed and banks of the stream.



CLAY RAISING. OPEN WORKING.
MARLAND, NEAR TORRINGTON, NORTH DEVON.
By permission of North Devon Clay Company.

It will, therefore, be seen that ball clays are to be traced usually to sedimentary deposits, being often finer in particle, and hence more plastic, than *China clays*, owing to the attrition which has taken place in the former case. An examination of a clay deposit will usually enable an intelligent observer to come to a conclusion as to its qualities, by keeping in mind the natural influences under which it was originally formed.

OTHER CONSTITUENTS OF NATURAL CLAYS.

It has been pointed out that foreign materials, other than pure clay, always exist in the natural clays, being mostly intermingled by the action of rushing water previous to their deposition. It is necessary to notice the most important of these.

Felspar and Mica.—These are the sources of alkali in the clay mass, and tend to increase its fusibility. They both occur intermingled in an impalpable condition, though mica is often to be found in a coarser state. The fine particles of mica are, however, far more plastic than those of felspar.

Silica.—This occurs in fine particles of sand and quartz, often in very large proportion, and is termed in chemical analysis "free" silica, in distinction from the silica combined with the alumina in the clay itself. The physical condition of this free silica in the mass is of great importance to the potter, as it reduces plasticity and fusibility, and also reduces shrinkage.

Iron Oxides.—These occur in clays formed from ferruginous sources, often in the state of iron carbonate; sometimes in the state of hydrated oxide, or as iron pyrites. The effect of these on the colour of the clay varies, sometimes giving red, and at others giving yellow tints, according to the quantity present.

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Lime and Magnesia.—These occur as carbonates in the clay from the decomposition of lime or magnesia rocks; or from the infiltration of water charged with lime in solution. Both these materials reduce plasticity, but to a less degree than silica.

Gypsum or Calcium Sulphate is also sometimes found in the crystalline state or in nodules, and is, therefore, more easily removed than other impurities which occur in pulverised state.

Non-Plastic Pottery Materials.

The plasticity of pure clay would be too great for most purposes of clay working and manufacture. The presence of non-plastic ingredients in certain proportions is therefore beneficial. The amount of such materials required depends on the character of the manufacture. In coarser goods, natural clays, having suitable non-plastic elements already admixed, are usually employed. For fine pottery, however, non-plastic materials, which open the body and increase or reduce its vitreous properties, are added in the exact proportions required.

Such materials may be classified as silicious, calcareous, or carbonaceous, according to their composition.

When non-plastic material is required having the same properties as the clay itself, it is customary to fire and pulverize the natural clay, which is then termed "grog," "grit," or "rough stuff."

Silicious ingredients.—*Silica* plays a most important part in all ceramics, and its proportion is considerably greater than that of any other material. Its influence varies according to the amount used. It not only reduces plasticity and reduces shrinkage, but also acts either as a refractory material or as a flux under certain conditions.

Silica, though obtained from a variety of sources, occurs in two distinct forms. These are termed *Crystalline* and *Amorphous*.

Crystalline Silica is best exemplified in rock crystal and flint, but is also to be found as quartz in comparative purity. The usual source of supply is flint or sand, though the purity of the latter is liable to be contaminated by the presence of foreign matter, which is difficult to remove owing to the small size of the particles.

Amorphous Silica occurs in nature in the form of infusorial earth and some other materials. It is, however, usually obtained by artificial treatment of crystalline silica, generally by heating to a high temperature, thus destroying the crystalline form.

It also assumes the amorphous condition when combined with bases or when disengaged from hydro-silicate of alumina by firing.

The specific gravity of crystalline silica is 2·6 to 2·7, while that of amorphous silica is only 2·2 to 2·3.

The change of form from crystalline to amorphous condition under prolonged heating reduces the density to this extent, at the same time increasing the volume 16 per cent. or 17 per cent.

To this fact is due the comparatively small shrinkage of sandy clays, in which the expansion of the sand crystals during firing counteracts the extreme shrinkage of the clay portion of the material.

Quartz is found disseminated through various natural rocks, but is not often obtained from this source. In certain parts of the Continent and elsewhere it occurs in large blocks of tolerable purity.

Flint occurs chiefly in boulders or pebbles which are usually gathered from the sea-shore at the foot of chalk cliffs, from which the sea is continually washing them out. They are, however, sometimes extracted direct from the chalk deposit. They have then, however, the drawback of contamination with the chalky surface, which the washing of the tides removes in the former case.

The chief source of supply is from the mouth of the Somme river, in Northern France, where many miles of shore are thus covered, the beds being constantly replenished by natural causes.

Sand, being the detritus of crystalline silica and other rocks, is often contaminated more or less. The character of such foreign ingredients affords a means of qualifying the material. Thus, a *quartz* sand is that containing, say, 98 per cent. of silica and upwards. It is termed *felspathic*, or *ferruginous*, or *calcareous*, or *micaceous* when these materials enter largely into its composition. The composition of sand should therefore have careful attention.

The form of the sand particles is also of much importance to the potter. In *water-washed sand* the particles are rounded by attrition of the tide or flow. *Quarry sand*, however, usually contains particles having sharp angles, and is therefore preferred owing to its superior binding qualities in the mass.

Ferruginous sand is used for opening red clay bodies, such as terra-cotta and red glazed bricks.

Micaceous and *felspathic sand* is used to increase fusibility, thus counteracting the refractory properties introduced at the same

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time by the quartz particles associated with them.

Calcareous sand is usually to be avoided in pottery manufacture, especially when the calcareous portions are in a granular form, causing disintegration when fired.

The use of *sea-washed sand* should be avoided, owing to the mixture of saline particles.

FUSIBLE MATERIALS.

1.—*Calcareous fluxes.*—*Lime* occurs mostly in two forms—either as chalk and marble (calcium carbonate) or gypsum (calcium sulphate). Lime is highly refractory, but forms fusible compounds with silica and other acid bodies. Owing to the property of thus acting as a flux, it is sometimes added to pottery bodies as *carbonate*, for the purposes of increasing their fusibility. The large amount of carbon dioxide in this material (44 per cent.) has, however, the effect of rendering the body porous when this is driven off. Unless the firing attains a sufficient temperature (between 700 C. and 800 C.) this chemical action does not take place, and until then calcareous silicates, which help vitrifaction, are not formed.

Another objection to the presence of lime salts arises from their partial solubility. This causes the water used in formation to dissolve a certain amount of lime, which, by the process of evaporation, is liable to produce a white efflorescence.

Calcium *sulphate* is even more detrimental, because the displacement of the sulphur trioxide by the silicic acid is not readily accomplished, as in the case of carbon dioxide.

Calcareous marls afford another means of introducing calcium carbonate into bodies. They consist of a mixture of this earth with clay, but the proportion is extremely variable, even in the same deposit. These marls become more plastic as the proportion of calcareous material decreases.

2.—*Alkaline Fluxes.* *Alkalies* used are either (A) *soda*, or (B) *potash*, both of which are soluble, and are therefore usually calcined with other materials before being introduced.

The ancient potters often used (C) *vegetable ashes*, containing alkali as a substitute, and at the present day majolica makers in some cases adopt this method.

Soda is often used in the form of (D) *borax*, which is also fritted or calcined to check solubility.

(E) *Sodium silicate*, or water glass, is also occasionally used for certain processes.

(F) *Felspar.* It is, however, preferable to introduce these fluxes in an indirect or more diluted form. Felspar forms a very convenient material for this purpose, owing to the low percentage of alkali, combined with other silicates most suitable for the potter's purpose, which it contains.

Felspar is widely distributed, but very few beds are of sufficient purity. Those of Norway are generally adopted on account of their good quality.

The following is an analysis of this deposit :—

Silica . . .	64·44
Alumina . . .	18·75
Ferric oxide . .	0·33
Lime . . .	0·01
Magnesia . .	0·25
Potash . . .	13·82
Soda . . .	2.40
	100·00

It will be noticed that the alkali contained in this felspar is chiefly potash, and is usually termed *orthoclase*. There are, however, some varieties which contain a predominance of soda. These are called *oligoclase*. An analysis of this material, found in Haute-Vienne, France, is here given :—

Silica . . .	67·63
Alumina . . .	20·48
Lime . . .	0·65
Soda . . .	10·26

Similar felspars are to be found in some parts of the United States.

In addition to the fusible materials already mentioned, there are several others occasionally used which can only be named. They are :—

Magnesia, in the form of *dolomite*, or *magnesite*, chiefly for porcelain and glazes.

Iron, in the form of *ferrous oxide*, chiefly for colouring purposes.

Calcium Phosphate, in the form of calcined bones, chiefly for china manufacture.

The details concerning the compounding of these materials into clay bodies and glazes for pottery purposes will be dealt with later on.

(To be continued.)

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THEORY OF STRUCTURAL DESIGN.

PART V.

By E. FIANDER ETCHELLS, A.M.I. Mech.E.

Moments of Inertia.

WE are now in a position to take up the problem of the internal resistance to bending.

We have previously learned that the turning moments of the forces to the left of any cross-section are balanced by the turning moments of the forces to the right of that section. Instead of considering these resultant moments as clockwise and anti-clockwise, or positive and negative, let us look at them from another point of view. Let us extend our conception of action and reaction. If we consider the moment of the forces to the left of any cross-section as being the turning moment at that section, we may consider the moment of the forces to the right of the section, as the *resisting* moment, or *reacting* moment; and *vice versâ*.

Now it is very essential to realise that these antagonistic tendencies to rotation can only balance each other by setting up stresses across the vertical section under consideration: just as the rotary force of a ship's engine can only act on the propeller *viâ* the propeller shaft; and just as the pull of competing tug-of-war teams is transmitted through the fibres of the rope.

In the latter case, with teams of equal strength, neither side will gain ground, and each half of the rope will be held in equilibrium by the pull of the other half of the rope and the pull of the near team.

In the case of the beam each half is kept in equilibrium by virtue of the equality existing between the turning moment on one side of the section, and the moment of internal resistance to turning, which occurs at the section given.

In other words, the external bending moment produces an internal resistance to rotation which acts from one side of a section, on the material on the other side, and thus serves to nullify the rotary tendency of the bending moment.

Let us construct a model, which may help to illustrate the foregoing.

Our model may not illustrate the method of loading a beam, but it will enable the stresses which occur in a beam to be traced from point to point, along clearly marked lines. In Fig. 33, the bending is produced by couples exerted on the ends of the beam. I believe that this luminous method is due to Professor Perry, F.R.S.

A couple may be defined as two equal forces acting in parallel and opposite directions, as AB in Fig. No. 33. The turning moment of a couple is equal to the magnitude of either of the forces multiplied by the perpendicular distance between their lines of action. Couples are said to be equal when they have the same turning moment; so that two oppositely directed forces of 2 tons, at 12 feet apart, are equal in effect to two such forces of 3 tons at 8 feet apart.

In Fig. No. 33, the couple AB produces the equivalent couple *f.d.* acting on G H where f = compression in rod, E G = tension in chain F H, and d = distance between the rod and the chain.

The portion C D H G is prevented from

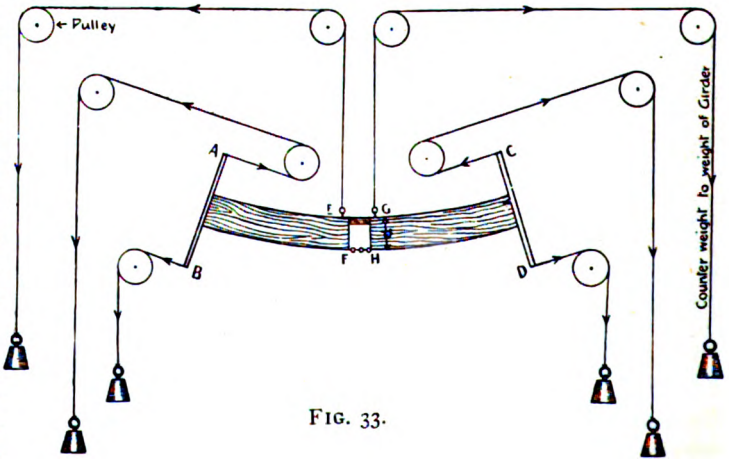

FIG. 33.

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rotation by the mutual opposition of the two couples C D and E F.

E F is of course merely the resultant of the couple A B. The rod E G is thus thrown into compression, and the chain F H suffers an equivalent tensile stress. For a practical example of this principle, let us take up the moment of resistance of a solid rectangular beam, with ends freely supported and carrying a uniformly distributed load.

Let us assume a beam with considerable deflection; and in order to give greater vividness to our ideas, let us try to think of the beam as consisting of a greater number of horizontal layers or laminations. In passing from the upper fibres, which are in compression, to the lower fibres which are in tension, it should be clear that we must pass through a layer at which the stress will be zero.

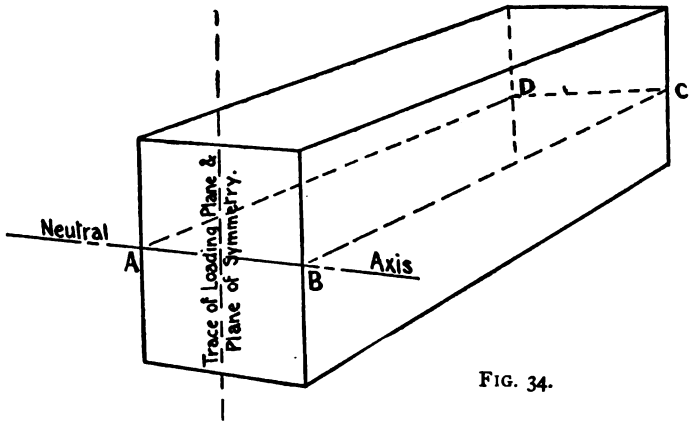

FIG. 34.

This layer, which may be infinitesimally thin, is sometimes called the *neutral surface.* For a rectangular beam and for a rolled steel joist, this neutral surface will lie midway between the upper and lower faces of the beam, and will be parallel thereto.

The *neutral axis* is an imaginary horizontal line which forms the intersection of the neutral surface and any vertical plane section selected. It is the axis round which it is most convenient to take our bending moments and moments of resistance.

In Fig. 34, A B C D represent points lying in the neutral surface. The stress is greatest at the extreme upper and lower fibres and is zero at the neutral axis. The stress in any particular fibre or horizontal layer of fibres is proportional to the distance from the neutral axis.

Let p = the compressive or tensile stress (*i.e.*, force per unit area) at one inch from the neutral axis. Let f_x = the stress at any other distance x

$$\text{Then } \frac{1 \text{ inch}}{x \text{ inches}} = \frac{p}{f_x}$$

$$\therefore f_x = p\,x$$

Let d = depth of beam. When $x = d/2$ the stress becomes equal to $pd/2$. This is the stress on the extreme fibres, and is usually denoted by the letter f.

It is shown in many of the text books, that in the case of symmetrical steel beams the stresses on either side of the neutral axis are similar in magnitude, intensity and distribution, and that although they are different in character they assist each other in maintaining equilibrium. It follows from this that we need only consider the upper or lower portion of our cross section, and afterwards multiply our results by 2, to give us the moment of resistance of the whole section.

Merely for purposes of illustration, let us take a beam 8″ deep, and let p, the stress at one inch from the neutral axis, = 2 tons per square inch. Take a vertical line representing the depth of the beam, and against this set horizontal lines to represent the intensity of the compressive and tensile stresses at the various distances.

Using the equation $f_x = p\,x$ we obtain the following table:—

Values of x . .	4	3	2	1	0	-1	-2	-3	-4
Values of f_x . .	8	6	4	2	0	-2	-4	-6	-8

These are plotted in Fig. 35. Here negative values of x indicate that the corresponding points are below the neutral axis. The negative values of f_x indicate that the stress is of an opposite kind to the stress on the other side of the neutral axis; *i.e.*, if $+f_x$ indicates compression, then $-f_x$ indicates tension, and *vice versâ*.

Let us now confine our attention more particularly to the upper half of the beam.

It can be seen from an inspection of the diagram (Fig. No. 35) that the mean stress will be half the maximum. So that the mean stress will be

$$\frac{0 + \frac{pd}{2}}{2} = \frac{pd}{4}.$$

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The total stress on one-half of the beam = mean stress × ½ area of cross-section

$$= \frac{pd}{4} \times \frac{bd}{2} = \frac{bd^2}{8} p,$$

where b = breadth of beam in inches.

The mean stress for the half section is equal to the actual stress at a point midway between the neutral axis and the extreme fibres. This mid-point is not, however, the point at which the whole of the stress may be assumed to be concentrated. In other words, the position of mean stress is very different from the position of the "centre of pressure." This "centre of pressure" or position of the resultant of the varying stresses between the neutral axis and the extreme fibres passes through the centroid of the triangle OAB, *i.e.*, at a distance = $\frac{2}{3} \times \frac{d}{2} = \frac{d}{3}$ from the neutral axis. That the centroid of a triangle lies along the line indicated may be experimentally verified by finding the centre of gravity of any set square or other triangular lamina. The moment of the total stress on the half beam is readily found by multiplying the total stress by the arm of the centre of stress. That is: since moment = total force × lever arm, the resisting moment

$$= \frac{bd^2}{8} p \times \frac{d}{3} = \frac{bd^3}{24} p.$$

For the whole section the moment of resistance will be twice this amount, *i.e.*, $\frac{bd^3}{12} p$. It will be recollected that p represents the stress at one inch from the neutral axis, and it will be seen that $\frac{bd^3}{12}$ is a constant for any particular size of beam. This $\frac{1}{12} bd^3$ is obviously a magnitude dependent only on the geometrical properties, or dimensions of the beam, and is constant irrespective of any elastic or molecular properties of the material employed.

Mathematicians universally use the letter I to represent this geometrical constant. Whether a beam is made of cast iron, mild steel, brass, or wood, so long as the dimensions remain the same the values of I will be identical.

The factor which takes into account the quality of the material, its strength, its working stress, is the factor p.

We have so far only taken a rectangular section, but each particular shape and size of section has a particular and special value of I. Where variously shaped beams are all in the same quality of the same material, these constants are indicative of the comparative strengths of the beams.

Since we know that the turning moment or bending moment is equal to the moment of resistance to bending, we know that in the case selected

$$\frac{Wl}{8} = \frac{1}{12} bd^3 \times p.$$

From this equation we can find the value of p. From the value of p we can find the value of f, and from this we can tell whether the maximum stress on the beam is excessive or reasonable.

The constant which I have called I is usually known by the name of *moment of*

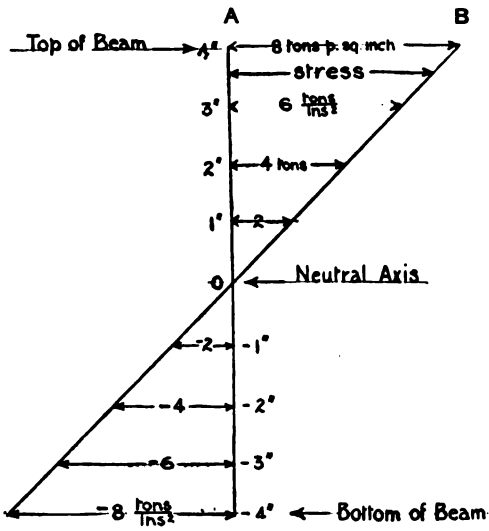

FIG. 35.

inertia. This term, though a natural result of philological and technological progress, has ultimately become an actual misnomer to the structural engineer, and a stumbling-block to the student.

It is customary to talk about the moment of inertia of an area; but an area has no thickness, and therefore no volume. That which has no volume can have no mass. That which has no mass can have no inertia; and that which has no inertia can have no moment of inertia. Therefore to talk about the moment of inertia of an area, is strictly and literally to talk about that which has no existence. The term only becomes rational when invested with a secondary figurative meaning.

Euler (1707 to 1783) first introduced the

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term, justifiably and in its primitive sense, because he saw analogies between the equations for moving and revolving masses. The next step was the perception, by other mathematicians, of certain similarities between equations used in beam formulæ and equations used in estimating the energy in revolving flywheels. This resemblance is of an abstract mathematical nature, rather than any physical resemblance between beams and flywheels. It is, therefore, only natural that a certain class of students should wonder why the moment of inertia of a cast iron beam is not appreciably different from the moment of inertia of the pine-wood pattern from which the beam was moulded. I have tried to show that in the theory of structural design the term moment of inertia has quite lost its original and literal meaning, but there are many other words which have passed through strange vicissitudes and taken up two or more conflicting meanings. For instance, "to bolt" may mean "to fasten," or "to run away." Another instance is the word "moment," given in Part I. of this series. Probably the literal and original meaning of the reader's own Christian or surname has become, for him, absolutely meaningless, or a glaring misnomer. I need not give other instances; every etymological dictionary is crowded with them.

The mechanical engineer still quite rightly talks about the moment of inertia of a flywheel, and to save ambiguity it has been suggested that the structural engineer and the architect should use the words "geometrical moment of inertia," or "second moment of area," or "the moment of a second degree for an area."

My personal objection to the phrase "geometrical moment of inertia" is that it is practically a paraphase of "moment of inertia of an area." Its chief advantage appears to be that it avoids confusion with the dynamical moment of inertia, and its disadvantage is its want of descriptiveness.

"The moment of second degree" and "the second moment of an area" are truer, more mathematical, but somewhat lengthier terms, and will appeal more to the mathematicians than to the hurried and harassed builder. Moreover, for many years to come we shall have to use the makers' section books, containing the old nomenclature.

Perhaps the easier reform would be to speak of the constant as I, just as we speak about the constants K, C, M, N, etc. We have an analogy to this denotation of a geometrical constant by a letter of the alphabet, when we make use of the Greek letter π for the ratio $\frac{\text{circumference.}}{\text{diameter.}}$ For π is merely the Greek initial letter of the word "periphery," and I believe we have also to thank Euler for bringing this useful symbol into general use.

(*To be continued.*)

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MICROSTRUCTURE OF SOME ALLOYS OF IRON.

By H. C. H. CARPENTER, M.A., Ph.D., of the National Physical Laboratory.

THE microscopic examination of certain of Professor Barrett's and Mr. Hadfield's alloys of iron, which has recently been carried out in the National Physical Laboratory at Teddington, arose out of the discussion following on their paper communicated to the Institution of Electrical Engineers about two years ago. Dr. Glazebrook threw out a suggestion that an investigation of the microstructure of the silicon-iron and aluminium-iron alloys, of which the magnetic properties appeared to be so remarkable, might be of value; and Professor Barrett readily supplied us with samples cut from these alloys, both in the cast and the rolled condition, as well as from his standard Swedish Charcoal Iron.

The valuable article on metallography from the pen of Mr. Hiorns, which appeared in the January number of "Technics," explained the scope of this comparatively new science. The article, however, deals somewhat scantily with the technique of grinding and polishing, and as success depends very largely upon this, the present writer proposes to describe the method actually employed in the manipulation of the alloys investigated, previous to their actual micrographic analysis.

Analyses of the three alloys were submitted to us as follows:—

Rods	Mark.	Percentages. Iron.	Carbon.	Silicon.	Sulphur.	Phosphor.	Aluminium.
Standard Iron	S.C.I.	99·89	0·028	0·07	0·005	0·004	...
Aluminium Iron	1167H	97·33	0·24	0·18	...	...	2·25
Silicon Iron	898 E.	97·30	0·20	2·50	...	...	...

Traces only of manganese were present. It will be noticed that the standard iron is of remarkable purity, containing, as it does, only about one-tenth of one per cent. of impurities.

The ingots corresponding to the rods were of irregular shape. Rectangular pieces of dimensions $\frac{1}{3}$ in. by $\frac{1}{3}$ in. by $\frac{1}{8}$ in. were cut. The diameter of the rods was about $\frac{1}{5}$ in. Transverse sections $\frac{1}{8}$ in. in thickness were cut from these. For cutting these sections an American power-driven hack-saw was used, but the metals were soft, and a hand hack-saw could have been employed quite well. The pieces were then surfaced with files used in the following order:—(1) rough, (2) smooth, (3) dead-smooth, the marks of each succeeding file being made *across* those of the preceding one.

The operation of grinding came next. The pieces were gripped mechanically by a holder: this moves backwards and forwards over the grinding blocks, which are mounted horizontally on spindles revolving about a vertical axis at the rate of about 2,000 revolutions per minute. The grinding machine used is driven by a one-twelfth horse-power electric motor, and three sections can be operated on simultaneously. The grinding blocks consist of well-turned wooden discs, upon which emery papers are securely fixed with glue. The writer has found that four such emery surfaces are sufficient, if used in the following order:—Nos. 1 and 0 (English), 0 and 00 (French). The pressure of the metal surface against the emery surface is regulated by a spring. In the case of soft metals, such as those examined in this instance, a *light* pressure is all that is necessary. The scratches produced by one emery surface are eliminated by the succeeding one. At the end of this process the metal should have a perceptible polish and only the faintest of scratches. Its surface is always worn down somewhat at the edge, owing to slight tilting of the metal section and the blocks, and if, as sometimes happens, it is necessary to photograph the edge, the difficulty can be met by imbedding the section in a ring of soft steel and grinding the composite material. The operation of grinding a specimen is tedious, and occupies fully half-an-hour, and sometimes more.

It is impossible, except in the case of the hardest metals and alloys, to produce a polished surface free from scratches by grinding them down on *dry* blocks. Polishing proper has to follow. This may be done on a flat disc, made of wood, ebonite, or metal, covered with cloth or leather, upon which the polishing powder is rubbed, and kept moist with water. The disc, mounted on one of the spindles of the grinding machine, was run at the same speed as the emery blocks. The polishing material used was a paste of

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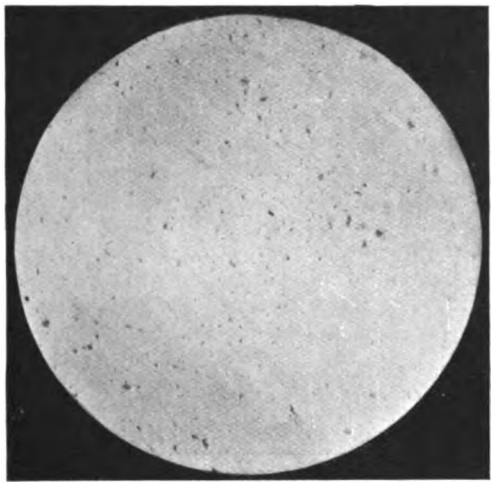

FIG. 1.—PHOTO-MICROGRAPH OF SWEDISH CHARCOAL IRON. PLANE POLISHED SURFACE.

(*Magnified* 50 *diameters.*)

alumina, "one-day powder" and Castile soap (for details of its preparation, *vide* "Notes on the Technology of Microscopic Metallography," published in "The Metallographist," vol. iv., page 1, from the pen of Professor Le Chatelier). Polishing should not take more than five minutes, and the metal or alloy should possess a clear, even polish.

The photo-micrograph reproduced in Fig. 1 shows the plane polished surface of the S.C.I rod, magnified fifty diameters. It will be seen that, except for the tiny dark patches, which are due to the presence of slag, the surface is white and structureless.

The method of illumination employed was as follows. The light from the positive crater of an arc lamp carrying 30 amperes with 45 volts between the terminals, is focussed on a vertical illuminator. This consisted of a prism, suitably mounted in a holder, placed between the tube and the objective of a Zeiss microscope, in such a position that the light was refracted downwards through the objectives on to the metal mounted on the mechanical stage, and passed back through the objectives past the prism, up the tube, and was brought to a focus at any desired position of the ground glass slide in the camera extension. Attention is directed to the fact that the light reflected by the metal surface was not strictly normal, but very lightly oblique. It is only, however, at magnifications above 500 that this would render it difficult to get uniform definition of that part of the metal surface under examination.

With this method of illumination, the surface of the standard iron appears white, because the light incident upon it is practically normal and is reflected entirely back up the tube. The slag spots, on the other hand, are dark, because they are not worn down by the grinding and polishing methods, they do not possess a plane surface, they reflect light at various angles, and only some of it at most, and in certain cases none of it, returns up the tube.

The first point to be emphasised is, that the plane polished metal surface, while indispensable to the success of microscopic investigation, in itself gives no information as to the structure. The reason for this has only been clearly shown within the last two years. Readers are referred to Mr. George Beilby's brilliant lecture, the third Hurter Memorial lecture, on "The Surface Structure of Solids" ("Journal of the Society of Chemical Industry," vol. xxii., No. 21), where a convincing exposition is given of the conclusions drawn from a large number of experiments which show "That the operations of cutting, filing, grinding, or polishing, produce on the surface of solids a thin film which is in many respects essentially different from the body underneath it."

Accordingly, this film has to be removed before the structure of a metal can be examined. The method which has been followed in the present investigation has been to dissolve the film with a 1 per cent. solution of nitric acid in absolute alcohol, after which the structure comes up and the

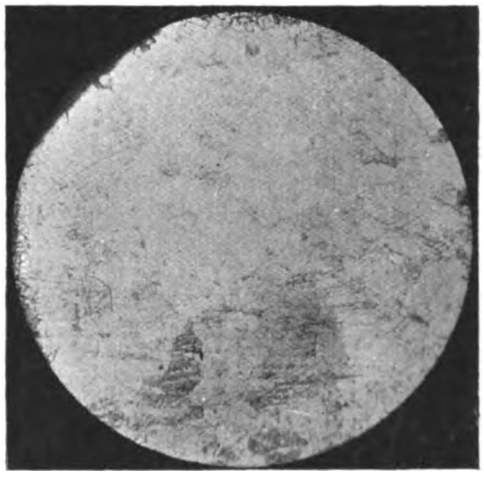

FIG. 2.—PHOTO-MICROGRAPH OF SWEDISH CHARCOAL IRON. ETCHED SURFACE.

(*Magnified* 50 *diameters.*)

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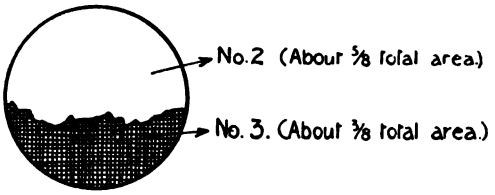

FIG. 2A.—TO ILLUSTRATE TYPES OF STRUCTURE OBSERVED IN SWEDISH CHARCOAL IRON.

surface is said to be "etched." If the etching is continued the metal underneath the film can be removed to any desired depth. The structures were, however, duplicated in the case of the S.C.I. rod by using a 5 per cent. picric acid solution in alcohol.

Contrary to expectation, the etched surface of the S.C.I. rod was found to be wanting in uniformity. Two distinct types of structure, in different parts of the same transverse section, were met with. Figures 2 and 3 illustrate the two types found, and the accompanying diagram (Fig. 2a) illustrates broadly (1) the distribution of the types, (2) the relative proportion.

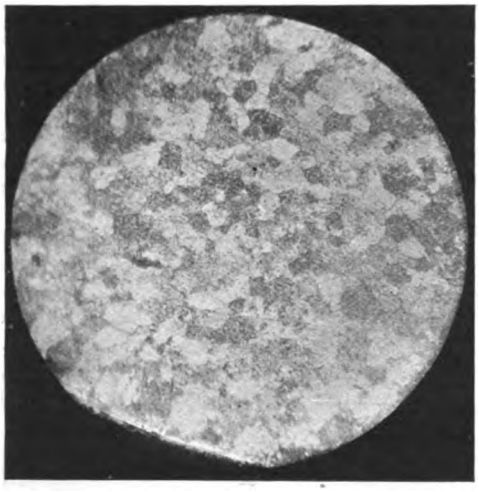

FIG. 3.—PHOTO-MICROGRAPH OF CHARCOAL IRON. ETCHED SURFACE.

(*Magnified* 50 *diameters.*)

The structure shown in Fig. 2 is that of an iron poor in carbon, that in Fig. 3 is of an iron containing a moderate amount of carbon. The etched surface shows a number of "grains," most of which are white in Fig. 2, while only about half are white in Fig. 3. Each of these white grains (one of which is shown in Fig. 4, in the centre of the field) consists of a number of small iron crystals, the orientation of which is the same for one and the same grain, but, as a rule, different from one grain to another. The individual crystals only appear after very deep etching. The grains appear white because their surface is evenly removed by the etching reagent. It is otherwise with the grains shown in Fig. 3. A high power photo-micrograph of a dark and a white grain is seen in Fig. 5. The dark grain on the left consists of a mixture of iron and iron carbide (Fe_3 C). This mixture, which appears in steels under various aspects, sometimes in the form of bands alternately light and dark,

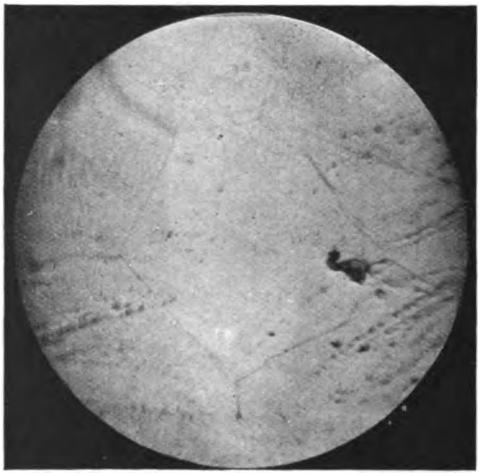

FIG. 4.—PHOTO-MICROGRAPH OF CHARCOAL IRON. ETCHED SURFACE.

(*Magnified* 360 *diameters.*)

FIG. 5.—PHOTO-MICROGRAPH OF SWEDISH CHARCOAL IRON. ETCHED SURFACE.

(*Magnified* 360 *diameters.*)

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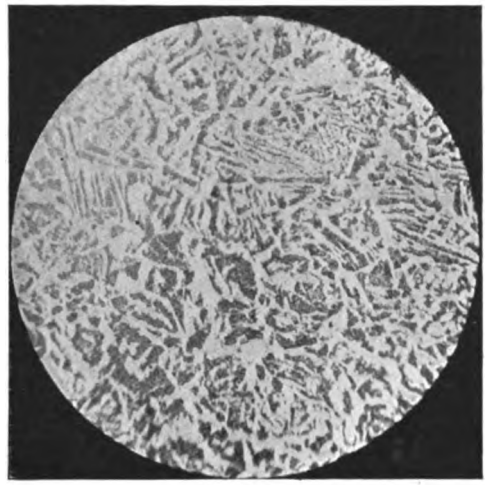

FIG. 6.—PHOTO-MICROGRAPH OF SWEDISH CHARCOAL IRON. ETCHED SURFACE.
(*Magnified* 50 *diameters.*)

sometimes in the granular state depicted here, is called *pearlite.* The surface is unequally etched, and normal light incident upon it is not completely reflected up the microscope tube.

The reason for the unequal distribution of pearlite in the standard iron, and its localisation as depicted in the diagram, was eventually found to be that the rod had been "heated to redness in a gas flame." * Direct contact between the flame and the rod carburised the latter locally; and a chemical analysis showed that the average percentage of carbon present had gone up from 0·028 to 0·045. Emphasis is laid on this fact, which has to be taken into consideration in discussing the evidence afforded by the photo-micrographs.

An examination of the structure of the ingot from which the material of the standard iron rod was obtained, revealed the fact that it consisted almost entirely of iron grains of the form shown in Fig. 2, but that in one or two places there was a considerable aggregation of slag patches, an example of which is illustrated in Fig. 6. These patches are for the most part removed by the hammering and rolling of the rod.

It is not possible to state matters so precisely in the case of the aluminium iron and silicon iron rods. A photo-micrograph taken of the edge of the ingot corresponding to the former (1167 H.) is seen in No. 7. The edge is represented by the white part, and consists probably of iron, and little else. The dark patches situated above, which stand in relief, are possibly due to the aluminium oxide; while the flattened layers, for the most part alternately white and grey, represent a complex mixture of iron, carbide of iron, aluminium and oxide of aluminium. This description applies to the rod, 1167 H. with one alteration, *viz.*, that the structure of the interior of the rod is not laminated, but distinctly cellular. A high-power photo-micrograph of the cellular structure is seen in No. 10. From this it is apparent that the cellular appearance is caused by a spiral formation of nodules on a greyish background, the dark patch in the lower half of the photo-micrograph being a shadow cast by one of them. (It will be remembered that the influence of the slight obliquity of the light at magnifications above 500 has already been referred to). Particular attention must be paid to the fact that a layer of what appears to be pure iron, varying in thickness from about $\frac{1}{150}$ to $\frac{1}{600}$ of an inch, occurs right round the surface of the rod.

Considerably deeper etching brings up the structure seen in Fig. 9. The boundaries of the grains are clearly seen. Some of these grains are about $\frac{1}{30}$th of an inch in diameter, others are less than $\frac{1}{1200}$th. The white irregularly-shaped patches on the dark triangular grain in the centre of the field stand in relief, for it is possible to focus *down* their edges on to the dark groundwork. It is not unlikely that these patches consist of aluminium, which has been rendered

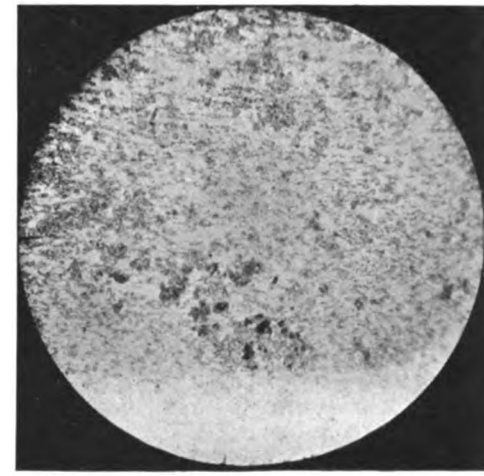

FIG. 7.—PHOTO-MICROGRAPH OF ALUMINIUM-IRON INGOT. ETCHED SURFACE.
(*Magnified* 50 *diameters.*)

* Proc. Elect. Engineers, 1902. Pt. 156, vol. 31, p. 37.

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passive by treatment with the nitric acid used for etching, but this is not to be taken as anything more than a suggestion.

Professor Barrett also sent for examination a specimen of rod 1167 H, which had been drawn down to a smaller diameter, and

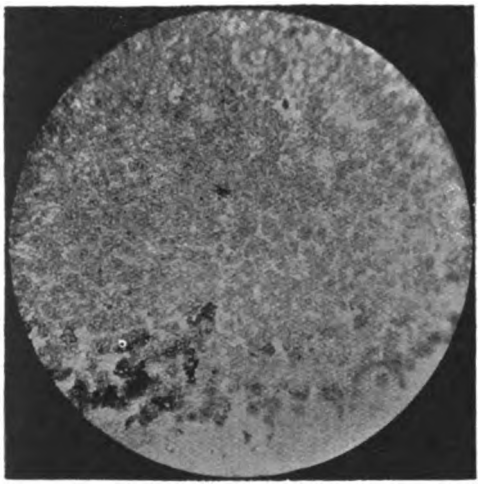

FIG. 8.—PHOTO-MICROGRAPH OF ALUMINIUM-IRON ROD, 1167 H. ETCHED SURFACE.
(*Magnified* 50 *diameters*).

FIG. 9.—PHOTO-MICROGRAPH OF ALUMINIUM-IRON ROD, 1167 H. ETCHED SURFACE.
(*Magnified* 50 *diameters.*)

with which he had not obtained such good results for magnetic permeability. Two essential points of difference from the original rod were observed. (1) There was no layer of pure iron situated on the edge, and (2) The white areas referred to in Fig. 9 were absent. Exactly the same two differences were noticed in comparing the structure of the silicon-iron rod, 898 E, with that of 1167 H. A typical structure is seen in Fig. 11, taken on the edge of the rod. The similarity between the structures of rods

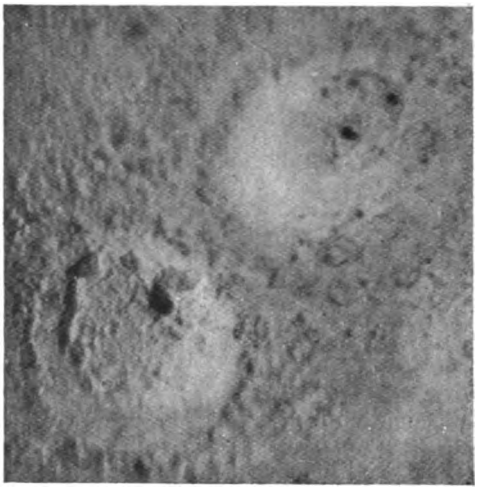

FIG. 10.—PHOTO-MICROGRAPH OF ALUMINIUM-IRON ROD, 1167 H. ETCHED SURFACE.
(*Magnified* 1200 *diameters.*)

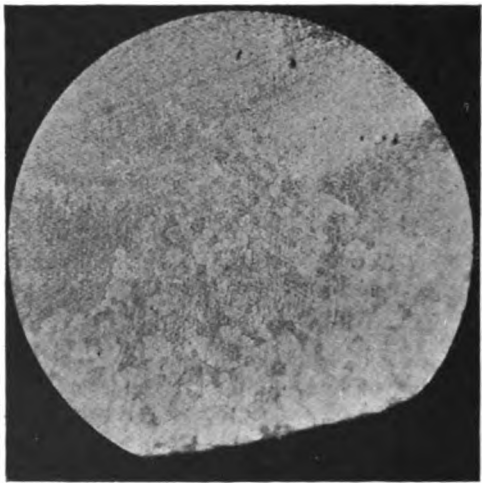

FIG. 11.—PHOTO-MICROGRAPH OF SILICON-IRON ROD, 898 E. ETCHED SURFACE.
(*Magnified* 50 *diameters.*)

1167 H drawn down, and 898 E was noteworthy.

DISCUSSION OF RESULTS.

It may be considered that the photo-micrographs throw some light on the results recorded in Barrett, Brown, and Hadfield's

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paper, but they cannot be said to do much more than this. The experimental basis is not sufficiently broad. In illustration of what is meant by this, it is only necessary to point out that, according to the analyses given in the paper just referred to, the carbon-content of rod 1167 H is eight times, and that of rod 898 E is seven times the carbon-content of rod S.C.I. The different values for magnetic permeabilities found for these three rods may be connected, not merely with the presence or absence of aluminium or silicon, but also with that of carbon, and the mutual influences of these on one another, as well as their particular influence on the iron. Accordingly, it seems most desirable to extend the number of alloys already experimented with, in such a way that while, *e.g.*, the aluminium content is kept approximately constant, the carbon percentage is varied, and *vice versâ*. In this way the influence of each constituent can first be found. But, considering the results of the photo-micrographic examination broadly, two striking facts are brought to light, which differentiate rod 1167 H from rods 1167 H drawn down, 898 E and S.C.I., and which may be connected with the high magnetic permeability of the first-named rod.

(i.) A layer of apparently pure iron of somewhat varying thickness, probably about $\frac{1}{250}$th of an inch on the average, occurs on the outside of the rod the whole way round. It forms about 10 per cent. of the total area.

(ii.) White patches in relief are seen scattered throughout the interior of the rod 1167 H. It may be that these consist of aluminium which has either not dissolved in the iron, or, if it was once dissolved, has separated out on cooling.

If this be the case, then the iron is purer than that in the silicon alloy, which appears to retain the whole of the silicon—other than that oxidised to silica—in solution. Part of the aluminium has no doubt been oxidised to alumina. It is a very puzzling fact that the white patches are absent from rod 1167 H drawn down.

It is quite intelligible that the thin layer of iron at the edge of rod 1167 H may be partly, and perhaps largely responsible for its high magnetic sensitiveness, especially when it is remembered that in the standard iron rod, owing to its having been partly carbonised at the edge, the layer of iron does not extend more than about half-way round. But it is evident that this does not afford a complete explanation, for the silicon iron rod, which possesses a greater magnetic sensitiveness than the standard iron rod, does not contain this fringe of pure iron at its surface.

The writer is disposed to think that the microscopical examination of these alloys also affords evidence which is in harmony with an explanation of the action of aluminium and silicon, tentatively put forward by Barrett and Hadfield, before the microscopic work was begun. They suggested that the action of these substances might consist in the removal of oxygen, or in the decomposition of oxide of iron, thus purifying the iron and thereby raising its magnetic permeability. It is quite possible that the small nodules met with in the interior of the rods 1167 H and 898 E are tiny particles of alumina and silica respectively, and, if this be so, they must certainly be taken into account in considering the cause of the high magnetic permeability of these rods.

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PRACTICAL SOLID GEOMETRY.

By G. F. BURN, Head of the Mechanical Engineering Department, Leeds Technical School.

THE object of this article is to describe a method of folding solutions of problems on orthographic projection, in such a manner as to completely verify the processes.

First, let a square piece of thin cardboard be cut out (Fig. 1), of 3″ side; it should be cut half through, folded half over along A B, and fitted in the first dihedral angle of the coordinate planes, as indicated in Fig. 2, so that if A B represent a line in space, *a b* will be the plan, and *a′ b′* the elevation. The model should be used in what follows.

Imagine a line A B in space, as in Fig. 3. If the plan, *a b*, and the elevation, *a′ b′*, be assumed anywhere in the planes of projections, it will be observed that by drawing projectors through the extremities of these projections, they will meet in A B—the actual line in space; and, by producing *a′ b′* and *a b* to meet the ground line, X Y, the elevation (marked h′. t′.), of the horizontal trace, and the plan of the vertical trace are located. Then h. t. and v′. t′. are at once found by drawing perpendiculars to X Y, which adequately represent the traces of the line. If A B be produced both ways, it will, of course, pass through both traces, as shown.

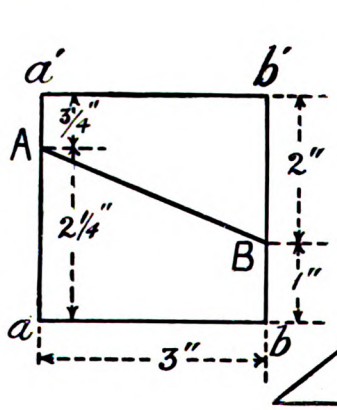

FIG. 1.
SIZE OF CARDBOARD.

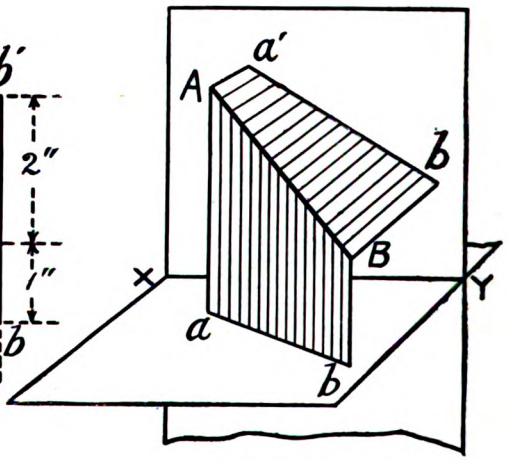

FIG. 2.
BENT CARDBOARD PLACED ON THE CO-ORDINATE PLANES.

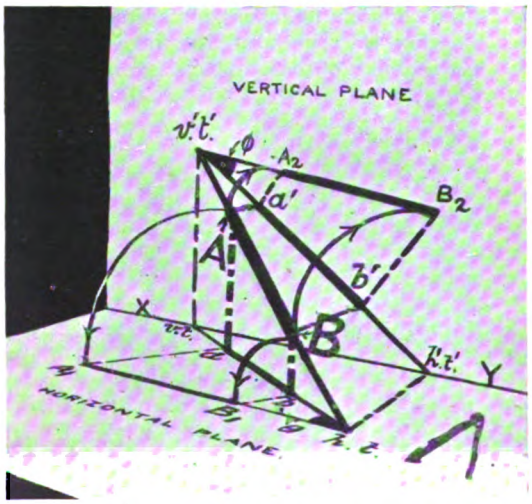

FIG. 3.—PHOTOGRAPH OF A TEACHER'S MODEL OF A LINE *A B* IN SPACE, TOGETHER WITH ITS PROJECTIONS, TRACES, INCLINATIONS, AND TRUE LENGTH.

Referring to the projection on the horizontal plane, the form of the plane figure A B *b a* is quadrilateral, with right angles at *a* and *b*. If, therefore, the true shape of the quadrilateral be constructed on plan *a b* as a base, and folded over, or rabatted, into the horizontal plane, about *a b* as an axis, we obtain the figure A_1 B_1 *b a*, giving in the horizontal plane the actual size of the quadrilateral; and therefore A_1 B_1 is the true length of the line A B, while *a* A_1, *b* B_1, are the heights of the projectors through A and B respectively.

Further, if A_1 B_1 be produced to h.t., the angle so formed with the foreshortened

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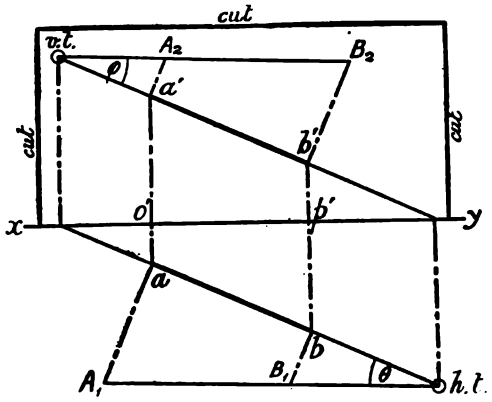

FIG. 4.—SHOWING THE PROJECTIONS OF A LINE A B, ITS TRACES, INCLINATIONS AND TRUE LENGTH.

plan, $a\ b$, is the angle of inclination, θ, of the line A B to the horizontal plane. In a similar manner, referring to the vertical plane, A B $b'\ a'$ is a second quadrilateral, with right angles at a' and b'. If, therefore, the true shape be constructed on the elevation $a'\ b'$, as a base, and rabatted into the vertical plane about $a'\ b'$ as a hinge-line, we obtain the figure $A_2\ B_2\ b'\ a'$, giving on the vertical plane the actual size of the quadrilateral; and therefore $A_2\ B_2$, is the true length of the line A B, while $a'\ A_2$, $b'\ B_2$, are the lengths of the projectors of A and B respectively from the vertical plane. Further, if $A_2\ B_2$ be produced to v'.t'., the angle, θ, so formed with the elevation $a'\ b'$ is the angle of inclination of the line A B to the vertical plane.

The beginner, having received this introduction to an important principle, is now prepared for the following problem:—*Given the projections a b, a' b', of an oblique line,* A B, *to determine* (1) *its traces;* (2) *its actual length;* (3) *its inclinations to the planes of projection.*

Determine the traces of the line (Fig. 4), and at the points a and b erect $a\ A_1$, $b\ B_1$, perpendiculars to $a\ b$, equal in lengths to $a'_1\ a'_1$, $b'_1\ b'_1$, the heights of A and B respectively. Join $A_1\ B_1$, and produce to h. t. θ is the inclination of A B to the horizontal plane, and A B is the actual length of the line. In a similar manner, the inclination ϕ, of A B to the vertical plane is obtained.

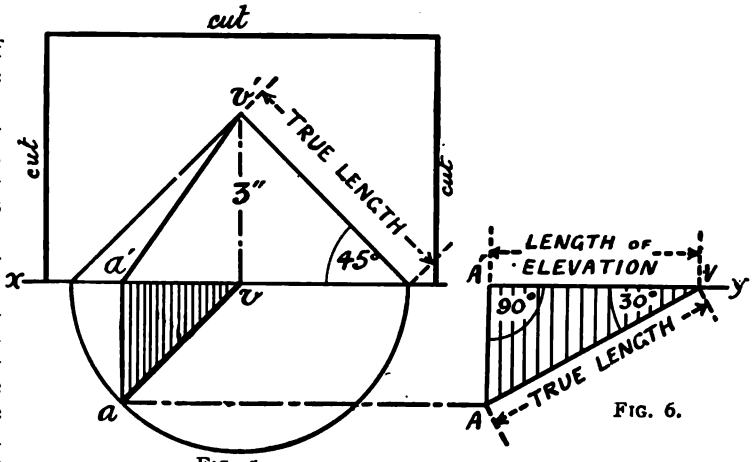

FIG. 5.
SHOWING A LINE INCLINED TO THE CO-ORDINATE PLANES.

FIG. 6.

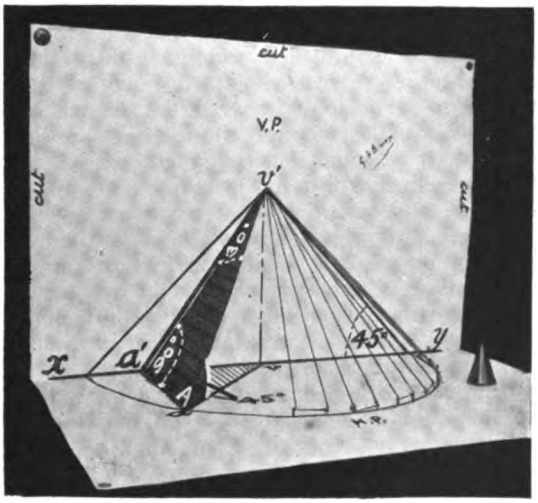

FIG. 7.—PHOTOGRAPH OF A TEACHER'S MODEL SHOWING AN OBLIQUE LINE ON THE CURVED SURFACE OF A SEMI-CONE.

Now cut through the three border lines above $x\ y$, as shown in strong lines, and rotate the piece cut about $x\ y$, till the vertical plane is represented in its natural position. Cut also along the lines B_2 v. t. and $B_2\ b'$; likewise cut A_1 h.t. and $A_1\ a$. Then, folding the triangles about their bases b' v. t. and a h. t. respectively, till they are at right angles to their planes, it will be found that the whole arrangement is in its natural position; $A_1\ B_1$ and $A_2\ B_2$ will coincide, and the reasoning for all the construction lines can be seen by means of this little model.

What might be regarded as the *pons*

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asinorum of the science of projection is to be found in the following problem :—

From a given point v, v', (in the vertical plane, and 3" above the horizontal plane) to draw a line v a, v' a', so that its inclination to the horizontal plane is 45°, and its inclination to the vertical plane is 30° ; the line to meet the horizontal plane in a, a'.

Figs. 5 and 6 form the solution, and show

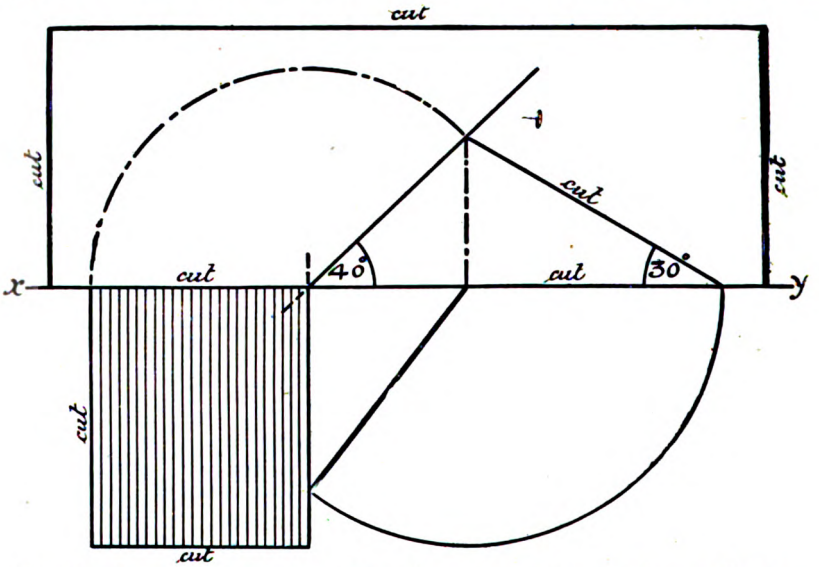

FIG. 8.—SHOWING HOW TO DRAW A LINE INCLINED AT 30° IN A PLANE INCLINED AT 40°, AND THE LINES TO BE CUT FOR EXPERIMENTAL VERIFICATION.

that when the usual semi-cone has been constructed, and the length of the required elevation has been determined, as in Fig. 6, the triangle of the latter figure may be cut out and removed, and the three border lines above *x y* of Fig. 5 likewise cut so as to make an extempore vertical plane when folded up. The paper triangle A A^1 V of Fig. 6 may now be placed in its true position, as indicated by the shaded triangle in Fig. 5. To convey a realistic impression of this problem, it is desirable to have the aid of a teacher's improvised model, as shown by Fig. 7, where it is seen that the hypotenuse of the shaded triangle (really the line under consideration) is supposed to lie on the curved surface of an imaginary half-cone, but is actually inclined as required.

Problems involving plane surfaces, or solids with plane surfaces, inclined to one of the planes of projection, lend themselves to easy treatment when once a student acquires the habit advocated. Rectangles, triangles, circles, etc., can be cut, save one side or small portion of the figure, about which it is supposed it can be hinged. For such a line the term " hinge " may be used. One of the planes of projection can likewise be cut and folded, in order that it might make an angle of 90° with its companion co-ordinate plane, when the whole can be viewed in its natural position. Thus Fig. 8 possesses interesting features when looked at from our point of view. Here a plane is given, inclined at 40° to the horizontal plane only, and it may be cut from the shaded portion at three sides only as indicated, leaving the side corresponding to the horizontal trace of the plane, about which it is folded into the inclined position stated. A right-angled triangle, with hypotenuse inclined at 30°, is also cut along two sides and hinged about its altitude. If the three border lines, shown above *x y*, be now cut through, it is possible to fold the various portions in such a manner that the hypotenuse of the triangle may be brought into the inclined plane, clearly demonstrating that a straight line can be situated in any given plane provided its inclination is equal to, or less than, that of the plane. Much can be done with this little model.

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BAUXITE AND ITS CHEMICAL USES.

By J. CASH.

THE use of Bauxite is not by any means confined to the production of aluminium, though it is, commercially, the chief source of that metal. The mineral substance—which Ireland, as well as France, furnishes in considerable quantity—is composed largely of the oxides of iron and aluminium; and besides being employed on a large scale by the British Aluminium Company in their important and growing industry, yields some titanium compounds which are being put to valuable use in this country for dyeing and other purposes. The manufacture of these compounds is carried out at the Manchester Aluminium Works of Messrs. Peter Spence and Sons, Limited, the only establishment in existence where they are produced on a commercial scale.

As regards its chemical properties, titanium stands about mid-way between silicon and tin. Some eighteen years ago, a Lancashire chemist, Mr. J. Barnes, suggested that its compounds might be used with advantage as mordants in dyeing. Experiments in this direction resulted in the production of some dyed textiles which, at the Royal Jubilee Exhibition, held in Manchester in 1887, attracted attention, not only by the brilliance of their colours, but also by the extraordinary fastness of the colours to light. Further researches by Mr. Barnes, and by Professor Knecht, of the Manchester School of Technology, and Mr. Charles Lamb—as also by Dr. Dreher, in Germany—established the commercial value of titanium compounds: especially for colouring tanned leather in all shades, from orange to brown; and some three years ago Dr. Knecht found that the titanous compounds were, for certain purposes, even more valuable than the titanic, principally as acid reducing agents.

An account of the manufacture of these compounds was given by Mr. H. Spence, at a recent meeting of the Manchester Section of the Society of Dyers and Colourists. Bauxite is largely used by the firm in the production of aluminium compounds, and the insoluble refuse yields titanic acid in a concentrated form. The acid is soluble only in hydrofluoric and concentrated sulphuric acids. The former of these is, for obvious reasons, not available; and in experimenting with the latter, in the form of sodium bisulphate, a new compound, which has proved of considerable technical interest, was discovered. This compound consists of basic titanium, sodium sulphate, of the formula $Ti\,OSO_4\,Na_2\,SO_4$, crystallised with water in well-defined needles. The salt is only slowly, though completely, soluble in water, requiring agitation over a considerable time to produce a saturated solution. One hundred parts of cold water dissolve about thirty parts of the double sulphate; and it is decomposed by hot water. The potassium and ammonium salts are readily prepared, and, apart from less solubility, have similar properties. Still more basic sulphates exist, soluble in part, in dilute sulphuric acid. From the sodium salt the ortho-hydrate of titanic acid is conveniently prepared, and forms a ready means of producing the soluble titanium salt for which the ortho-hydrate is required. Both the titanous and titanic compounds are manufactured by Messrs. Spence—the former by the electrolytic process.

One of the salts of titanium which has found very considerable and extending application, particularly in the leather industry, is titanium potassium oxalate, a basic salt which forms well-defined crystals of the composition $Ti\,O\,C_2\,O_4\,K_2\,C_2\,O_4\,H_2\,O$. It is freely soluble in hot water. A solution of titanium tannate in oxalic acid, known as titanium tannooxalate, has been found by Messrs. Spence to be the most convenient form for applying to vegetable fibre as a self-colour, or for mordanting purposes; and it is also more suitable for certain purposes in leather dyeing and staining than crystallised oxalate. This is especially the case with chrome tanned and alumed leathers. For mordanting purposes, it is prepared with a somewhat higher proportion of tannic acid than that for use in leather work. The high solubility of the ammonium and the sodium salts is in marked contrast to the slight solubility of titanium potassium fluoride. In comparison with stannous chloride, titanous dichloride is at least twenty times more powerful as a reducing agent with azo colours. The results of one or two comparative tests, given by Mr. Spence in the course of his paper, are interesting. Cotton yarn dyed with Benzo 4B

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was put into boiling water, and 2 per cent. solution of tin crystals added until decolourised (time about forty-five minutes). The same experiment was done with Ti Cl_3 solution of the same strength. It was found that a fairly full shade required about $2\frac{1}{2}$ per cent. of Ti Cl_3 to destroy it. Of stannous chloride 28·5 times as much was required. Similarly, cotton dyed with chrysophenine required 37·2 times as much tin crystal as Ti Cl_3. In another experiment, cotton yarn dyed with Benzo 4B required 2 per cent. Ti Cl_3 and the equivalent of 37 per cent. of zinc, in the form of sodium hydrosulphite prepared according to the indigo book of the Badische Anilin and Soda Fabrik.

Dr. Knecht, who has played so large a part in technical investigations, was the first to indicate many of the purposes to which titanous salts are applicable. He drew attention last year, in the *Berichte*, to their powerful reducing action on organic compounds—indigo, for example—and on other bodies. Employing dilute solutions of titanous salts, he has worked out some very valuable analytical methods for the volumetric estimation of azo dyes of nitro and nitroso compounds, and of ferric iron. Dr. Knecht has the further credit of the application of titanous salts to the discharge of azo and other dyes, whether in stripping, clearing, discharge or resist work. For the former there is no acid reducing agent which is comparable with titanous salts for efficiency; but though the same would naturally be held to apply to discharge and resist work in calico printing, this has not so far been satisfactorily demonstrated.

From some cause, which has not up to the present been fully elucidated, the powerful reducing properties of titanous sesquioxide salts have not been generally available for this purpose. This difficulty, however, will probably be surmounted. A process has recently been patented by the Bleachers' Association for the reduction, by means of dilute titanous salt solutions of oxycellulose, on cotton and similar textiles, with the object of avoiding the formation of stains and light-coloured patches frequently caused by its presence. The patches "tendered" by the presence of oxy-cellulose are stated to be materially strengthened by the treatment. Still more recently the Farbewerke (formerly Yeister, Lucius and Brüning) have claimed the catalytic action of small amounts of titanous oxide salts for the reduction *in situ* of organic compounds, such as nitro-benzine and quinone (which are reduced to aniline and hydroquinone respectively)—the $Ti_2 O_3$ being continuously regenerated electrolytically. A low current density is employed.

Mr. Spence pointed out two new applications of titanium salts which have promise of an important future. Mr. Lamb has carried out a very careful investigation of the tanning properties of titanic acid, which he finds produces a very good leather free from the green colour of the chrome-tanned product; and the continued investigation of the process is affording encouraging results. The second application is that in which the fire-proofing properties of titanic acid play a chief rôle. Salts of alumina, tungstic acid, and other oxides, have for many years been known to exert a certain fire-proofing effect on textiles and other inflammable substances to which they have been applied; but this property appears to be possessed by titanic acid to a degree in excess of anything hitherto known. This method of fire-proofing has been the subject of several patents. The titanic acid may readily be fixed alone, in the material to be proofed; or may be fixed in conjunction with other oxides, such as stannic acid and silica, both of which have fire-proofing properties to some extent. A more important feature is the remarkable degree with which titanic acid may be incorporated with the fibre. The materials may be dyed at the boil, after the proofing process, without detriment; and the titanic acid may be fixed so as to become, in effect, an integral part of the fibre. Unlike tungstic acid, which has a tendency to combine with alkali and become soluble, titanic acid is unaffected by soap or alkaline attack, and continual repeated washing has little or no appreciable effect. The degree to which such highly inflammable materials as flannelette, lace, and other substances of a similar nature may be rendered non-inflammable is remarkable; and should, as Mr. Spence pointed out, go a long way to prevent the appalling loss of life, not only in such catastrophes at that in Chicago a few months ago, but in the child-life of our own country.

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THE FORMATION OF LOOPS.
AND
THE CONSTRUCTION OF LOOPED FABRICS

By JAMES HY. QUILTER, F.K.C.

LOOP formation as a study is somewhat neglected, its principles being based on so simple a foundation that even a child at school becomes acquainted with them in some form or other, and their use comes to be looked upon more as a hobby than as the means of a development towards art. Thus, the industry of frame-work knitting lacks the artistic designers found in some of the other industries that deal with thread-like substances as their raw material.

Frame-work knitting, however, differs essentially from all other textile fabrics, inasmuch as the threads are bent into regularly loop-like forms which hang in each other, and are thus strictly loops bent out of the thread in the form of two symmetrical letters S standing opposite to each other.

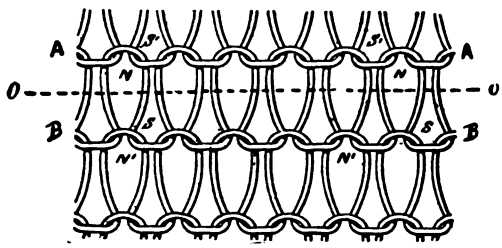

FIG. 1.

The simplest form of a looped fabric is shown at Fig. 1.

A A shows a row of such loops which, for demonstrative purposes, is divided through the centre by dotted line O. The upper loops N are termed needle loops, and the lower loops S sinker loops, the first-named being formed on the needles, while the last-named are formed by sinkers or other dividers passing between the needles. Each row of loops, or any number of rows, is formed from one continuous thread, as from A to A. The needle loops of each row hang supported on the following row of sinker loops, as N hangs upon S^1, the lower loops S supporting the previously made row of loops as S supports N^1, these positions of the various loops being seen from the back of the fabric.

The art of loop formation depends on the variety of ways in which such loops can be manipulated, without deviating from the main principles explained, by such methods as varying the lengths of loops, the shifting of

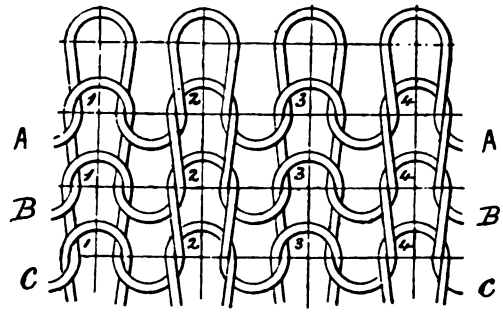

FIG. 2.

one or other of the loops, accumulation of same, or other similar means.

Fig. 2 shows one of the simplest forms of loops, in which each alternate needle loop lies in a reverse position. At each row of loops, loops 1 and 3 lie in same position as the loops shown at Fig. 1, while the needle loops 2 and 4 are laid at the back of the needle loops, or reverse to those of 1 and 3. This is the basis of loop formation of ribbed fabrics, which by the peculiar formation of the loops gives even greater elasticity than the plain formation, and so produces a fabric more adaptable for garments where such elasticity is essential for clinging purposes, and has the particular feature of having the same character on both sides of the fabric.

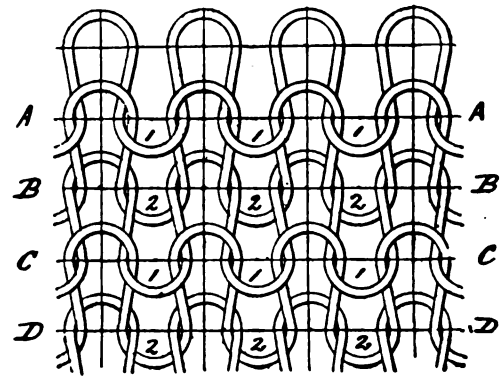

FIG. 3.

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Fig. 3 explains a variation of the simple loops by the reversing of the position of the loops, not at alternate needles, as previously explained, but at alternate rows. The needle loops of rows A and C lie all to the front, while those of rows B and D lie to the back. This, of necessity, also alters the position of the lower loops, those of 1 all lying to the front, while those of 2 are at the back. This

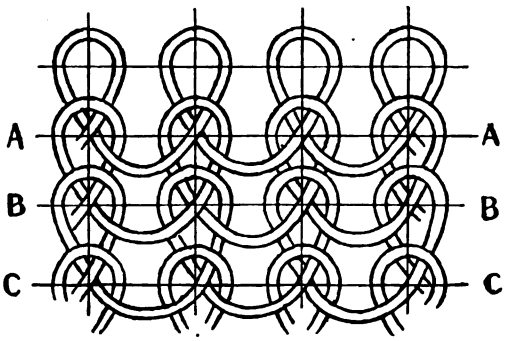

Fig. 4.

fabric has a similar peculiarity to that of Fig. 2, by reason of each side of the fabric being similar in appearance. It has not, however, the same particular elasticity, being more of the character of fabric formed as shown in Fig. 1.

Fig. 4 shows an example of the formation of twisted loops. The whole of the needle loops retain the same position as in the plain formation, but a twist of loop occurs as shown, thus giving an entirely different formation to

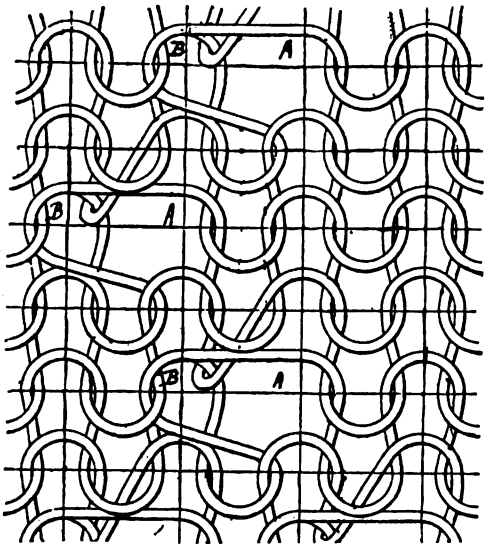

Fig. 5.

the lower or sinker loops. This produces a distinctly peculiar appearance to a fabric so composed, and different from any other void of the twist. The whole of the loops, however, have the same peculiarity and each row of loops lies exactly similar to each other row.

One of the first studies in loop formation is that of how loops may be shifted from one position to another to produce special desired effects. Having two loops with which to deal, the effect may be considerably altered by the removal of one or the other, and again by altering such loops as regards position and direction.

The simplest of the two loops to deal with is undoubtedly the needle loop, and this may be partially removed from one needle to another, as shown at Fig. 5.

When half a loop only is taken from needle A, and put upon needle B, a shift may be made in either direction for the purpose of forming small openings in a fabric in those

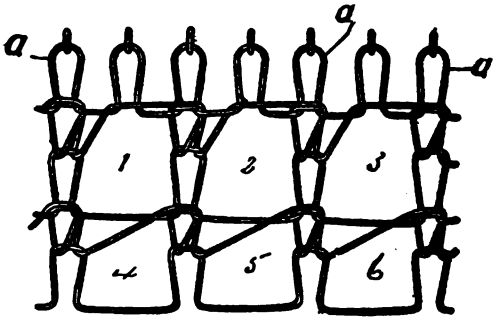

Fig. 6.

places from which the half loops are removed, as at A, and the forming of thickenings or small elevations where the extra half stitch has been put, as at B. By such arrangement of openings or elevations, names, letters, figures, or other designs may be worked. The total removal of a needle loop has even a more distinct object in the forming of more pronounced openings, with the result that knitted fabrics can be produced which have a lace-like appearance. One method of producing this effect is shown in Fig. 6: *a a* shows a complete row of loops, while in previous rows, openings 1, 2, 3, 4, 5, 6 have been made by the removal of the needle loops as shown.

Fig. 6 shows manipulation of the lower loops B (Fig. 1), and introduces a more difficult problem than that of moving the loops A; as during the making of a complete row of loops B which are to be moved, they have to be caught by special points and held until the

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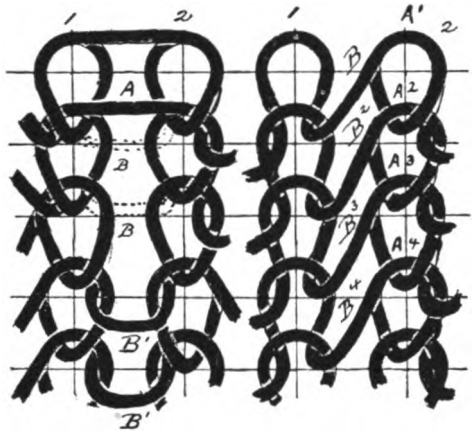

FIG. 7.

row is completed. They are then returned back by these points on to certain needles. The special kind of point denotes how the loop shall be deposited. By one system the loop B may be returned over two needles, as shown at 1, Fig. 7. The two original loops B have been lifted and thrown over both needles, 1 and 2, the remaining loops B are shown at B^1 B^1 in their original position. The loops B are made much longer than similar loops in other fabrics, owing to this manipulation. At 2 the loops are shown thrown over one needle, only loops A at 1 being in their original position, while loops 2 have the loops B upon them as shown, B^1 being over A^1, B^2 over A^2, etc. The effect on the fabric in this case is two-fold, causing elevations and openings of various sizes; the former by the drawing together of the loops A and lifting them into small projections; the openings being formed by the long loops B, which are allowed to remain in their original position.

Another and even more important manipulation of looping is that of the accumulating of loops, as this system forms the basis for a variety of plain and fancy fabrics on both the principles of plain knitting (Fig. 1), and rib knitting (Fig. 2). The question of art in knitting is applied as much in the accumulation of loops as in any other method, since by its means certain coloured threads may be used, each taking its own position, only to appear on the face of the fabric at such period and for such length as may be desired. Undoubtedly, the simplest form of loop accumulation is the double looping or working together of two threads as one during the formation of a plain knit fabric with loop formation, as at Fig. 1. In this principle fabrics are produced not by any variation of the form of loops whatever, but by the simple position of the threads, which are so looped that one always appears on the face of the fabric and the other at the back. While kept in such positions the two sides of the fabric show one thread each, but by the reversing of such threads, they being of suitable colours, designs may be made, as the position of the threads can be changed with such exactness that No. 1 thread may appear at the front at one needle with No. 2 thread behind it, and at the next needle No. 2 thread at the front with No. 1 thread behind.

Fig. 8 shows a design produced by such reversing of the loops, the face of the fabric being perfectly level with the ordinary characteristic of a plain knit fabric. The changing of the position of the two threads is controlled by special pattern mechanism. The design shown is 37 loops wide from A to B, and at each row the colours appear as shown, row A having 4 loops white, 2 black, 4 white, 3 black, 1 white, 3 black, 4 white, 10 black, 5 white and 1 black, the opposite or wrong side being coloured in reverse; in other rows the threads are reversed at the loops as shown.

Accumulating of loops by retaining certain loops on the needles for a varied number of courses, forms a basis of design for numerous classes of fabrics, for by this means colours may be made to appear in irregular form, with the result that designs show the two distinct characteristics of irregularity of looping and colouring.

Fig. 9 shows the simplest combination of such looping with one black thread A and a white

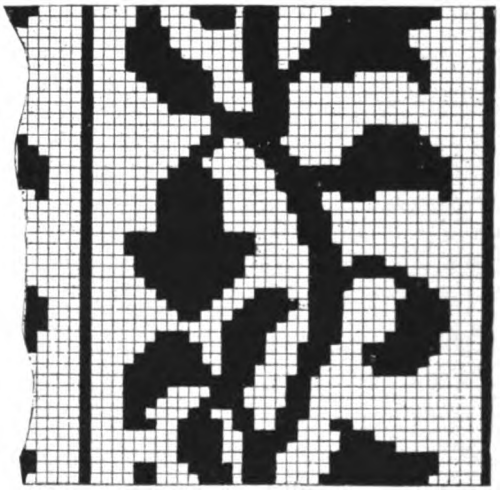

FIG. 8.

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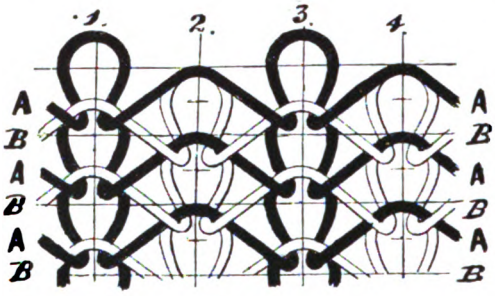

FIG. 9.

thread B. At needle 1 all completed loops are composed of the black thread, while the white as shown lies behind, and is therefore not seen on the face of the fabric. At needle 2 white loops are formed, and the black thread lies at the back as accumulated loops, there being two threads on each needle, one a completed loop, and the other a loose thread. At needle 3 the loops are same formation as at 1, and at 4 as at 2. Quite a number of loops can be so left upon the needles, and the longer such loops are held so more irregular become the adjoining loops, as, while the thread is held on the needle, that loop becomes longer by drawing thread from adjoining loops, which, of necessity, become shorter and more irregular. The number of rows held on the needle is, however, limited, as will be well understood, though as many as 6 or 8 can be retained in special cases.

Fig. 10 shows a combination having 3 loops held at A and at B. The irregularity of the loops is also shown.

Fig. 11 gives another combination, showing the effects of colouring. At rows *a* and *b*, a black thread is used, and other courses white; at *d* the black loop from row *a* has been held while 4 rows were made. The white thread in this example is not left on the needles to accumulate as a needle loop, but is let off each row, to lie as a loose loop at the back. When row *b* is made, loop *f* becomes drawn in to meet and loop with loop *d*. These two loops thus cover the space of the 4 rows *c*, and make a black vertical effect on the face of the fabric; while the effect on the

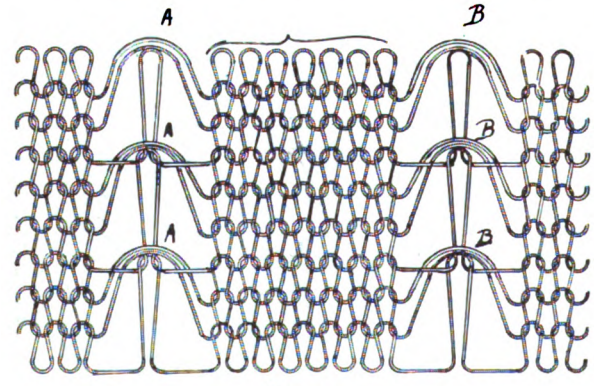

FIG. 10.

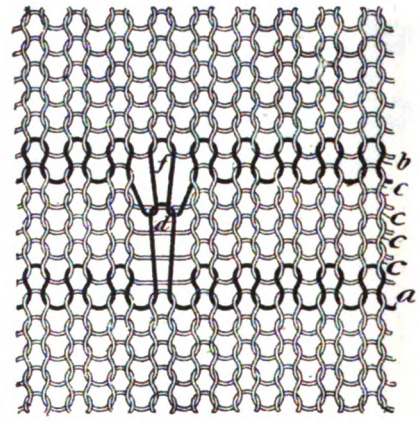

FIG. 11.

fabric would be the drawing-out of regularity the black loops on either side of loops *d* and *f* on rows *a* and *b*.

Fig. 12 illustrates an example of looping

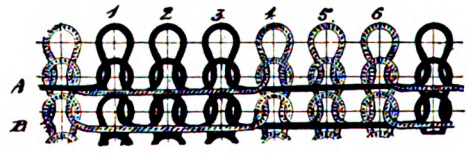

FIG. 12.

showing the one colour on 3 needles, the black thread A looping at needles 1, 2, 3 at each row, and the white thread B at needles 4, 5, 6, the black thread lying as a long loose thread behind needles 4, 5, 6, and the white thread behind needles 1, 2, 3.

Similar effects are produced on rib fabrics by this system of loop accumulation, but being rib, and the two sides of the fabric alike in loop formation, the effect produced is that the loops may be a different colour on the one side to the other, or at such needles as desired.

(*To be continued.*)

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A SIMPLE INSTRUMENT FOR MEASURING ANGLES.

THE present tendency is to make tuition in all subjects as practical as possible: this applies not only to the experimental sciences, but also to mathematics in all its branches. It is much easier, as well as being more interesting, to approach a subject like Trigonometry, so far as possible, from the practical side; but progress in this line has until recently been rendered difficult on account of the absence of simple apparatus for measuring angles. This difficulty has been removed by Mr. J. R. Erskine-Murray, who has patented the simple quadrant represented in Fig. 1. This consists of a graduated brass frame carrying a small fixed mirror A. This mirror possesses a vertical index mark which is adjusted to be exactly at the centre of the graduated circle. The plane of the mirror cuts the graduated circle at the zero graduation. A small travelling sight F, with a vertical slit H, moves round the graduated arc. In order to find the angle between any two objects L and K, it is only necessary to sight one of these, K, above the graduated mark on the mirror, while the other object, L, is seen reflected in the mirror immediately beneath the first. Then the scale reading in a line with the sighting slit gives the angle subtended by the two objects at the eye of the observer. This little piece of

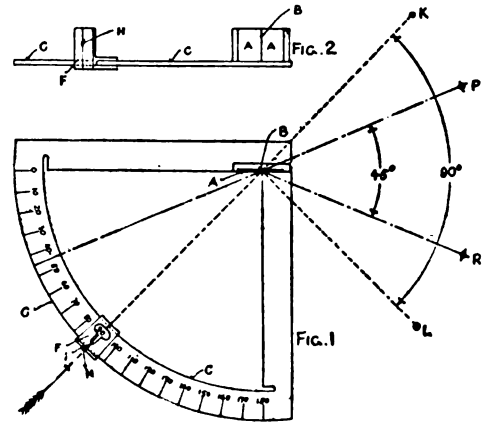

FIG. 2.

FIG. 1.

apparatus will go into a space of four inches square; and since there is practically nothing which can be put out of adjustment, it could be safely carried in the pocket, or entrusted to a person without special knowledge of scientific instruments.

REVIEWS.

Paint and Colour-Mixing: A practical Handbook for Painters, Decorators, and all who have to mix colours. By Arthur Seymour Jennings. Second edition, re-written and enlarged. pp. viii. + 139. (London: E. & F. Spon, Ltd., 1904.)

The contents of this book justify its sub-title. The house-painter is presented with methods of obtaining colours of almost every conceivable shade, both in oil-paint and distemper. Eight coloured plates are included, showing no less than 171 different colours. These plates should be of great service, as enabling the painter to select the exact tint he requires, and then, by using the appended instructions, to mix commercial paint-stuffs to obtain this tint. Some consideration of the chemical properties of certain paints might have proved advantageous, since certain mixed paints may initially possess a very attractive appearance, which is, however, rapidly marred by the chemical reactions occurring between the constituents. On the other hand, so long as the painter adheres to the rules laid down, he is unlikely to obtain failures of this kind: it is only when a man of inventive mind attempts to experiment, thus running off the beaten track, that purely scientific knowledge becomes indispensable. Chapter X. embodies some novel and useful methods of obtaining colours by mixing black japan with ordinary painter's colours of bright hue. A method of testing the suitability of the japan is given. A chapter on harmony in colour is included, and attention is devoted to brush-making, methods of removing paint, fire-resisting pigments, and the procedure necessary to test various commercial paints. Altogether the volume should be most useful to those for whom it was written.

Builders' Quantities. By Herbert C. Grubb, Lecturer in Quantities to the Beckenham Technical Institute. pp. viii. + 227. (London: Methuen & Co., 1904.) Price 4*s.* 6*d.*

The study of builders' quantities is important alike to the architect and the practical builder. Given the plans, elevations, and sections of a building, together with a specification of the materials to be employed, the cost of materials and labour may be calculated: the importance of this item in the production of an estimate is easily realised. The author treats the subject in a simple and yet adequate manner, all points which would present difficulties to the beginner being specially dealt with. In a preliminary chapter some important problems in mensuration are solved. Modes of measurement are then carefully discussed and illustrated, the book ending with worked examples of abstracting and billing. The illustrations are clearly drawn and well reproduced, and an excellent index is appended.

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Elementary Geometry of the straight line, circle, and plane rectilineal figures. By Cecil Hawkins, M.A., Senior Mathematical Master at Haileybury College. Parts I. and II. pp. viii. + 296. (London: Blackie & Son, Ltd., 1904.) Price 2*s.* each part.

The best method of teaching geometry to beginners is absorbing much attention: after years, during which the slightest deviation from the Euclidian system was decried as an outrage, we have reached a time when the necessity for change has been universally admitted. The exact extent to which change may be allowed to proceed is more or less a subject of dispute; but even the Cambridge Syndicate recognise that change is unavoidable. Euclid's order is no longer insisted upon, any proof being considered satisfactory if it apparently forms part of a systematic treatment of the subject. Accurate practical work is insisted on, and questions will be set to test geometrical knowledge, as distinguished from the capability of writing out book-work. To appreciate the advantage of a work written to fulfil these conditions, as compared with the ordinary Euclidian methods, one need only turn to p. 5, part I., of the above work. On this page the idea of an angle is communicated in a manner that can be readily understood by the veriest beginner. Altogether, Mr. Hawkins is to be congratulated on the books he has produced, which should play an important part in the reform of geometrical methods. The illustrations are good, a large number of examples are given, and a useful index is provided.

Simple Experiments in Static Electricity. A series of instructive and entertaining Experiments in Static Electricity for Students and Amateurs. By Percival G. Bull, M.A. pp. 71. (London: Percival Marshall & Co.) Price 6*d.* net.

This book contains a large number of attractive experiments, which may serve to interest students in a part of the science of electricity which has now-a-days fallen into a position of secondary importance; it may serve a yet more useful purpose in providing lecturers with details of experiments, many of which illustrate important principles. It is perhaps to be regretted that the author has not explained the experiments systematically from the point of view of lines of force, so successfully developed by Faraday; but, taken as it stands, it should prove a useful adjunct to the library of the teacher of electricity.

Radium, and all about it. By S. Bottone. pp. 96. (London: Whittaker & Co., 1904.) Price 1*s.* net.

That a book of 96 pages could contain everything about radium is of course a physical impossibility; the literature already accumulated on this subject would, if collected together, extend over several thousands of pages. Strictly speaking, Mr. Bottone has furnished us with a readable popular account of the most striking properties of radium known up to the present; it will doubtless be welcomed by many who wish to know something of this eccentric substance, without going to the trouble of mastering the scientific work which has already been carried out, and is still in course of progress.

The School Calendar. A Year Book of Scholarships and Examinations at Schools, Colleges, and Universities, for the year 1904, pp. 204. (London: Whittaker & Co, 1904.) Price 1*s.* net.

The title of this book sufficiently explains its scope. It only remains to be said that the idea of the book has been well and efficiently carried out; its usefulness goes without saying.

A Text Book on Ceramic Calculations. By W. Jackson, A.R.C.S., Lecturer on Pottery and Porcelain Manufacture for the Staffordshire Education Committee. pp. xviii. + 67. (London: Longmans, Green & Co., 1904). Price 3*s.* 6*d.*

The absence of concise and perspicuous handbooks has long been a drawback to the English potter and technical student.

Until lately, the science of Ceramics has been but imperfectly understood, and the practical potter has too often formulated his deductions from the most limited data. The want of some means for critically comparing the value of formulæ which tradition has handed down, and which have been often indiscriminately preserved and adopted, has seriously hindered the progress of the industry. Hence the potter has been unable to venture on any change in the use of recipes, apparently differing, but actually similar; nor has he had the means of calculating the requisite adjustment of formulæ, which may be necessary through the substitution of new materials. With the exception of a small pamphlet issued by the American Ceramic Society, no work treating of the subject has been published in this country.

Both the student and the manufacturer will therefore welcome this excellent little manual, which is all the more useful because it affords practical examples, and demonstrates the application of the methods and the equations propounded.

The methods of calculating the dry weights of material in slips, though not new, are concisely formulated and explained; while the fineness of material in bodies—a subject which has lately occupied the attention of the author—is also clearly dealt with.

Perhaps the most important part of the work is that which treats of synthesis. Few English potters have hitherto attempted to grapple with this subject, which is absolutely essential to the practical handling of ceramics on a scientific basis.

The examples here set out will be of the utmost value to students mastering the most useful branch of pottery research. To such the handbook affords a means of placing the pursuit of ceramic operations on a more systematic basis than has hitherto been the custom in this country.

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ANSWERS TO QUERIES.

Students wishing for the solution of problems, or assistance in their scientific or technical studies, are invited to consult the Technical Editor by letter. Queries should be accompanied by the name and address of the sender, together with a nom de plume *for publication. Queries obtained from text-books or examination papers should be accompanied by particulars of the sources from which they are derived. Queries should reach us before the 10th of the month, to be answered in the next month's issue. Each inquirer is restricted to one query per month.*

THEORY.—What constitution would you assign to the following compounds:—Pb O_2, Ba O_2, $Na_2 S_2 O_3$, K Cr O_3 Cl? **State the evidence in each case.**—*Board of Education, Chemistry Honours, Part I.*, 1903.

Pb O_2 (*Lead dioxide*, or *peroxide*), is doubtless the oxide corresponding to the salts of quadrivalent lead, hence it may be assigned the structure O = Pb = O.

In the periodic system lead occupies a position in the group which commences with silicon. The latter behaves consistently as a quadrivalent element, and has only one oxide, Si O_2, which is excessively difficult to reduce, and is acidic in character. An intermediate element, tin, forms two oxides, Sn O and Sn O_2, both forming salts with acids and with bases: the dioxide is stable when heated, but is easily reduced, *e.g.* by carbon. The analogy with lead is here complete, but lead dioxide is even more easily reduced than Sn O_2, being broken up by moderate heat.

Like Si O_2 and Sn O_2, lead dioxide yields salts with bases, *e.g.*, Ca_2 Pb O_4 (= 2 Ca O. Pb O_2), and is precipitated from these on adding acids. It may also be obtained by the action of alkalies on solutions of lead tetrachloride, Pb Cl_4, just as Sn O_2 may be prepared from stannic salts. There is, therefore, a clear gradation in properties in the passage from silica to lead dioxide, and these two compounds are to be considered as analogous.

Ba O_2 (*Barium peroxide*) is probably a salt of the weakly-acidic hydrogen peroxide, and must, therefore, be regarded as having the structure Ba$\begin{smallmatrix} O \\ | \\ O \end{smallmatrix}$ or Ba = O = O, according as hydrogen peroxide is written H – O – O – H or H$_{H}$>O = O, which is still a moot point.

Barium peroxide, like calcium and sodium peroxides, and unlike lead dioxide, yields hydrogen dioxide by double decomposition with acids; and, further, may be obtained in a hydrated form by mixing solutions of hydrogen peroxide and of barium hydrate.

$Na_2 S_2 O_3$ = "Sodium thiosulphate" is sodium sulphate $\begin{smallmatrix} O \\ O \end{smallmatrix}$>S<$\begin{smallmatrix} O\,Na \\ O\,Na \end{smallmatrix}$ in which one atom of oxygen has been replaced by sulphur, and is, therefore,

$\begin{smallmatrix} O \\ O \end{smallmatrix}$>S<$\begin{smallmatrix} O\,Na \\ S\,Na \end{smallmatrix}$ or $\begin{smallmatrix} O \\ S \end{smallmatrix}$>S<$\begin{smallmatrix} O\,Na \\ O\,Na \end{smallmatrix}$

Sulphur and oxygen are, as is well known, allied; and, in the divalent state more especially, form compounds similar in type and, broadly speaking, in chemical properties. This characteristic is exhibited in a striking way in the existence of numerous "thio" salts and acids; that is to say, compounds derived from others by the simple replacement of oxygen by sulphur, *e.g.*, K C N O and K C N S; $K_3 As O_4$, $K_3 As S_4$. This is explicable only on the assumption that the replacement of the one element by the other involves no further change of structure.

In the special case here dealt with there is additional evidence in favour of the analogy, as sodium sulphite absorbs oxygen to yield the sulphate, and sulphur to form the thiosulphate.

At the present time there is no evidence serving to distinguish with certainty between the two formulæ given above.

K Cr O_3 Cl. (*Potassium chlorochromate*) may be considered as intermediate in character between potassium chromate and chromyl dichloride: in other words, as the potassium salt of the half-chloride of chromic acid. This view is expressed by the formula $\begin{smallmatrix} O \\ O \end{smallmatrix}$>Cr<$\begin{smallmatrix} O\,K \\ Cl \end{smallmatrix}$

Chromium is allied to sulphur, the relationship being most clearly shewn in the analogies between the chromates and sulphates, which are isomorphous. Sulphuric acid yields several chlorides by replacement of hydroxyl by chlorine, and of these the most simple are sulphuryl dichloride $\begin{smallmatrix} O \\ O \end{smallmatrix}$>S<$\begin{smallmatrix} Cl \\ Cl \end{smallmatrix}$ and sulphuryl chlorhydrin $\begin{smallmatrix} O \\ O \end{smallmatrix}$>S<$\begin{smallmatrix} O\,H \\ Cl \end{smallmatrix}$, which are true acid chlorides; the former of these has its analogue in chromyl dichloride $\begin{smallmatrix} O \\ O \end{smallmatrix}$>Cr<$\begin{smallmatrix} Cl \\ Cl \end{smallmatrix}$ and the latter in potassium chlorochromate.

Sulphuryl chlorhydrin is prepared from fuming sulphuric acid by the action of hydrogen chloride, whilst potassium chlorochromate is made by the action of hydrochloric acid on the potassium salt of chromic acid. Both compounds are unstable towards water, the former yielding hydrogen chloride and sulphuric acid, and the latter, potassium chloride and chromic acid. A more direct proof of the acid-chloride-like character of the salt under consideration is adduced from its behaviour towards ammonia, with which it yields the stable compound K Cr O_3 NH_2, or "potassium amidochromate"; this property at once disposes of the view that the substance is merely a "molecular compound" of K Cl. and Cr O_3.

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WIRELESS.—What would be the cost of establishing wireless telegraphy communication between two points 17½ miles apart, and how small coils could be used?

We have made several efforts to obtain an idea of the cost of establishing wireless communication between two points 17½ miles apart, but as much depends upon local circumstances, such as the nature of the levels and country between the stations, it appears almost impossible to fix upon even an approximate figure with the data supplied. Two good 10-inch coils specially wound for the purpose would be required, and these would cost about £35 each. It would perhaps be better to apply to the Marconi Wireless Telegraph Company direct for particulars of the cost for the complete outfit.

ELEMENTARY.—Give dimensions of a boiler to hold 1,000 gallons at a minimum cost.

We presume that the boiler is to be cylindrical, with plane ends; and that the cost of the boiler is assumed to be proportional to the area of the cylindrical surface and the ends. In that case, the problem takes the form:—Find the dimensions of a cylindrical closed boiler of 1,000 gallons capacity, the cylindrical surface and ends having the smallest possible area.

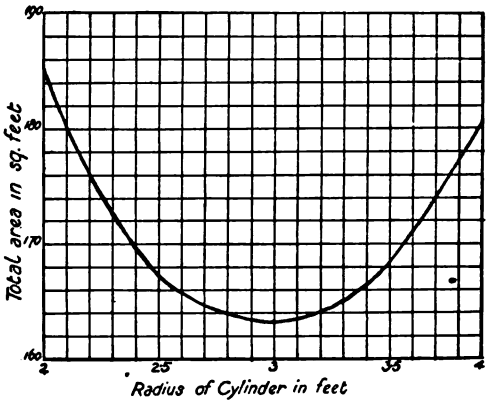

FIG. 1. (ELEMENTARY).

Let V = volume of boiler, in cubic ft. A gallon of water occupies a volume of 0·160 c. ft. (nearly), so that V = 1,000 × 0·160 = 160 c. ft.

Let r be the radius, and l the length of the cylinder, in ft. Then

$$V = \pi r^2 l \quad \therefore l = \frac{V}{\pi r^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Area of cylindrical surface $= 2\pi r \times l$
$= 2\pi r l$ sq. ft.

Area of each plane circular end $= \pi r^2$ sq. ft.

$\therefore$ Total area $= 2\pi r l + 2\pi r^2$ sq. ft. . . . (2)

Substituting in (2) the value of l obtained in (1), we obtain

$$\text{Total area} = \frac{2\pi r V}{\pi r^2} + 2\pi r^2$$

$$= \frac{320}{r} + 2\pi r^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

The value of r which will give the smallest possible value to the right-hand side of (3) can be found by a simple application of the differential calculus. It can also be found graphically, as in Fig. 1, by drawing a curve showing the values of the total area for various values of r. In Fig. 1, values of r are measured horizontally: the value of the right-hand side of (3), when r has any particular value, is plotted vertically above this value r. It will be seen that the total area has the smallest value when $r = 2{\cdot}94$ ft. Then

$$l = \frac{320}{\pi \times (2{\cdot}94)^2} = 11{\cdot}77 \text{ ft.}$$

Thus the cylinder must have a diameter of 2·94 ft., and a length of 11·77 ft.

LIGHT.—According to the wave theory of light, the illumination at any point is due only to a small area on a given wave surface, because all other rays which travel to that point approximately cut one another out. In the case of water waves intercepting one another, heat would probably be produced. I should be very pleased if you would explain to me into what form of energy the kinetic energy of light waves which intercept one another is turned.

It is not legitimate to speak of light *rays* intercepting one another; to be strictly accurate, we must consider each part of the wave front to emit secondary waves or wavelets, and it is these wavelets which interfere with, or reinforce each other. Consider a succession of wavelets radiating from two distinct points in a wave front. As these wavelets advance, one set overlaps the other: at certain points a crest of one system passes at the same instant as the trough of the other system, and these two annul each other. There is, however, no loss of energy. At other points a crest of one system passes at the same instant as the crest of the other system, with the result that the amplitude is doubled. Thus the energy which has disappeared from the points where interference takes place is transferred to the points where reinforcement occurs. The ether is a frictionless medium, and there is, therefore, no dissipation of energy in it.

MATRIC.—Explain clearly the terms "Geographical Meridian" and "Magnetic Meridian," and explain how you would practically determine each at a given place.—*London University, Matriculation*, 1903.

The geographical meridian at a given point on the earth's surface is an imaginary plane, drawn through the axis of rotation of the earth and the point in question. The axis of the earth is directed toward a particular point in the heavens, which lies near to the north star, and is called the celestial pole. As the earth rotates, the various stars appear to describe concentric circles about the celestial pole, and thus the position of this point can be found by observing the motion of any particular star. It can also be found by observing the apparent diurnal motion of the sun. At noon a vertical stick and its shadow lie in the geographical meridian.

The magnetic meridian, at a given point on the earth's surface, is an imaginary vertical

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plane, passing through the axis of a magnet freely suspended at that place. It may be found by observing the direction in which a compass needle points. For accurate determinations, corrections are required which would not be required to be discussed in answering the question given.

LAMBDA.—Find the first three components of a periodic disturbance, the displacement curve of which has the form of an isosceles triangle.— *Board of Education, Sound (Honours),* 1902.

Let Fig. 1 represent the displacement curve of the given periodic disturbance, the displacement being plotted vertically and the time t horizontally. Starting at the origin O, the displacement increases regularly until $t = T/2$ when it attains the value a. Then as t increases, the displacement regularly diminishes until it acquires the value 0 when $t = T$. Subsequently the displacement once more increases regularly, attaining the value a when $t = 3T/2$, after which it diminishes, reaching the value 0 when $t = 2T$, etc. Consequently the displacement curve is periodic

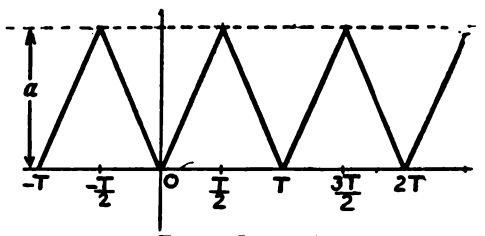

FIG. 1 (LAMBDA).

with respect to t, the period being T; and the value of the displacement is the same for positive and negative values of t which are numerically equal. Thus we must find a series of simple harmonic functions which is periodic with respect to t, having the period T; and the value of this series must be the same for $t = +t$, and $t = -t$. If, then, this series gives the displacement between $t = 0$ and $t = T/2$, it will give the displacement for all values of t; for it will necessarily represent the displacement from $t = 0$ to $t = -T/2$, and the complete displacement curve is merely a repetition of the part between $t = -T/2$ and $t = +T/2$.

Since the displacement must be the same for $t = +t_1$, and $t = -t_1$, it must be expanded in a series of cosines. This follows from the circumstance that $\cos\theta = \cos(-\theta)$. Between $t = 0$ and $t = +T/2$ the value of the displacement is equal to $\frac{at}{\frac{T}{2}}$ We therefore have

$$\frac{2at}{T} = A_0 + A_1\cos\frac{2\pi t}{T} + A_2\cos\frac{4\pi t}{T} + A_3\cos\frac{6\pi t}{T} + \ldots . (1)$$

It is easily seen that this series fulfils the conditions prescribed above; we must now determine the value of the coefficients A_0, A_1, A_2, . . . etc.

Let $2\pi t/T = x$. Then (1) takes the form

$$\frac{ax}{\pi} = A_0 + A_1\cos x + A_2\cos 2x + A_3\cos 3x + \ldots . + A_n\cos nx + \ldots . (2)$$

To determine any coefficient A_n, multiply both sides of (2) by $\cos nx\,dx$, and integrate from 0 to π It can be proved that, when this is done, the integral by which A_n is multiplied will have a finite value, while the integrals by which the other coefficients are multiplied will each be equal to zero. Thus we shall obtain A_n multiplied by a finite quantity on the right-hand side and a definite integral of determinate value on the left-hand side of the equation; so that the value of A_n becomes known.

Performing the above operation on a particular term $A_k\cos kx$ on the right-hand side of (2), we obtain

$$A_k\int_0^\pi \cos kx.\cos nx\,dx$$

$$= \frac{A_k}{2}\int_0^\pi \left\{\cos(n-k)x + \cos(n+k)x\right\}dx \ldots (3)$$

This is equal to zero, except when $k = n$. When $k = n$ (providing n is not equal to zero) the value of the integral on the right of (3) is equal to

$$\frac{A_n}{2}\left[x + \frac{\sin(n+k)x}{n+k}\right]_0^\pi = \frac{A_n}{2}\pi.$$

Consequently, on multiplying both sides of (2) by $\cos nx\,dx$ and integrating between the values 0 and π we obtain

$$\frac{a}{\pi}\int_0^\pi x\cos nx\,dx = \frac{A_n}{2}\pi \ldots . (4)$$

Now $\int x\cos nx\,dx$

$$= \frac{1}{n}x\sin nx - \frac{1}{n}\int \sin nx.\,dx$$

$$= \frac{1}{n}x\sin nx + \frac{1}{n^2}\cos nx$$

$$\therefore \int_0^\pi x\cos nx\,dx = \left[\frac{x\sin nx}{n} + \frac{\cos nx}{n^2}\right]_0^\pi$$

$$= -\frac{2}{n^2} \text{ when } n \text{ is odd; and}$$

$$= 0 \text{ when } n \text{ is even.}$$

Thus from (4)

$$A_n = -\frac{4}{\pi n^2}\cdot\frac{a}{\pi} = -\frac{4a}{\pi^2 n^2} \text{ when } n \text{ is odd;}$$

and = 0 when n is even . . . . . (5)

Thus the values of A_2, A_4, A_6, . . . will each be equal to zero. The values of A_1, A_3, A_5, . . . can be found by substituting $n = 1$, $n = 3$, $n = 5$ . . in (5). To find A_0, notice that when $k = n = 0$ is substituted in (3), the value of the integral on the right of that equation becomes equal to

$$\frac{A_0}{2}\left[x + x\right]_0^\pi = A_0.\pi.$$

Multiply the left-hand side of (2) by $\cos nx\,dx$ (where $n = 0$), and integrate: we obtain

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$$\frac{a}{\pi}\int_0^{\pi} x\,dx = \frac{a}{\pi}\cdot\frac{\pi^2}{2} = \frac{\pi a}{2}$$

$$A_0\pi = \frac{\pi a}{2};\ \therefore\ A_0 = \frac{a}{2}$$

Thus

$$\frac{ax}{\pi} = \frac{a}{2} - \frac{4a}{\pi^2}\left\{\cos x + \frac{1}{3^2}\cos 3x + \frac{1}{5^2}\cos 5x + \ldots\right\}$$

Therefore the required series is

$$\frac{a}{2} - \frac{4a}{\pi^2}\left\{\cos\frac{2\pi t}{T} + \frac{1}{9}\cos\frac{6\pi t}{T} + \frac{1}{25}\cos\frac{10\pi t}{T} + \ldots\right\}$$

The above solution is an instance of Fourier's theorem, that any periodic disturbance can be resolved into a series of simple harmonic components. For other similar problems, and a very thorough treatment of the whole subject, see *An Elementary Treatise on Fourier's Series and Spherical, Cylindrical, and Ellipsoidal Harmonies*, by W. E. Byerly, Ph.D. (Boston, U.S.A. : Ginn & Co., 1893).

TRIG.—The points A, B, C along a sea shore are in a straight line. Their distances apart are 2550 and 1617 yards respectively. From a ship A B subtends an angle 27° 32′ and B C an angle 41° 16′; find the distance of the ship from B.

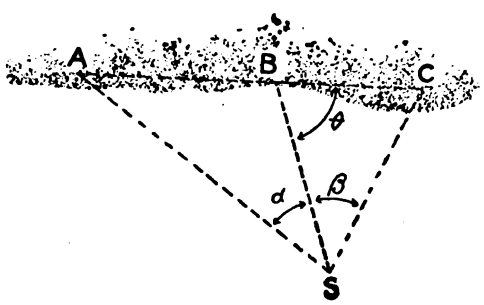

FIG. 1 (TRIG).

In Fig. 1, let A B = a, B C = b, and S B = x.

Then $\frac{x}{a} = \frac{\sin(\theta - a)}{\sin a}$.

$$\frac{x}{b} = \frac{\sin(\theta+\beta)}{\sin\beta}$$

Hence $\frac{x}{a}\sin a = \sin\theta\cos a - \cos\theta\sin a$

$$\frac{x}{b}\sin\beta = \sin\theta\cos\beta + \cos\theta\sin\beta.$$

From these we obtain

$$\cos\theta\sin(a+\beta) = x\left(\frac{\sin\beta\cos a}{a} - \frac{\sin a\cos\beta}{b}\right) \quad (1)$$

$$\sin\theta\sin(a+\beta) = x\sin a\sin\beta\left(\frac{1}{a}+\frac{1}{b}\right). \quad (2)$$

Divide (2) by (1) and obtain

$$\tan\theta = \frac{(a+b)\sin a\sin\beta}{b\sin\beta\cos a - a\cos\beta\sin a} = \frac{a+b}{b\cot a - a\cot\beta} \quad (3)$$

From this $\tan\theta$, and therefore θ, may be found, and hence x may be calculated from

$$x = ab\,\frac{\sin\theta\sin(a+\beta)}{(a+b)\sin a\sin\beta} \quad (4)$$

From (3)

$$\tan\theta = \frac{4167}{1617\cot 27^\circ 32' - 2550\cot 41^\circ 16'} = \frac{4167}{1950},$$

and $\theta = 64^\circ 55'$.

From (4)

$$x = \frac{1617\times 2550\times\sin 64^\circ 55'\times\sin 68^\circ 48'}{4167\times\sin 27^\circ 32'\times\sin 41^\circ 16'}$$

= 2740 yards (approximately).

CAUSTIC.—I should be greatly obliged if you would give me the following particulars relating to the Edison accumulator?

(*a*) What are the oxides of iron and nickel used as the active materials of the plates?

(*b*) What is the size of the perforations of the steel pockets?

(*c*) What distance apart are the plates?

(*d*) As two plates per cell are used, I suppose there is no advantage in using two negatives and one positive?

(*a*) The pockets in the positive plate are filled with nickel peroxide (NiO_2), while those in the negative plate are filled with finely divided iron. In both cases a small amount of graphite is mixed with the active material. The chemical constitution of the cell may be represented as follows :—

After charging, $Ni\,O_2$ | K H O | Fe.
After discharging, Ni O | K H O | Fe O.

(*b*), (*c*), and (*d*). Mr. Hibbert, in his paper on the Edison cell, states that each cell contains "fourteen positive and fourteen negative plates. Each plate is made of sheet-steel, nickel plated, punched with 18 holes of rectangular shape. In each of these holes is inserted a flat pouch or pocket containing the compressed active material. The walls of these pockets are perforated by extremely fine slots or holes, through which the liquid can penetrate.

"The plates are fixed very near each other. Yet there does not seem to be any danger of short circuits . . . Vulcanised rubber separators are put between the plates, making the whole a compact mass, whose stability is calculated to resist all the ordinary mechanical shocks it is likely to undergo."

PUZZLED.—Can you give any reason why a heated wire has a greater electrical resistance than a cold wire? Resistance varies inversely as the cross-sectional area of the wire: heat expands the wire; yet the heated wire offers a greater resistance.

The greater resistance offered by a heated wire is not due to the change of dimensions of the latter: it is probably due to some slight

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change in the molecular condition of the wire. At present we can do no more than guess at the mechanism by which electricity is conducted along a wire, and without this knowledge it is impossible to explain the effect of a change of temperature on resistance. Experiment has proved that the resistance of a pure metal diminishes as the temperature approaches the absolute zero (−273°C.). Thus it would appear that when the molecules of a pure metal are absolutely at rest, the metal becomes a perfect conductor of electricity; and we may hence infer that the increased resistance of a wire due to a rise of temperature is due in some way to the increased velocity of its molecules. Further than this we can scarcely go at present, without entering into the field of speculation.

SULLIVAN GALVANOMETER.—Will you be good enough to give me particulars of the following:—The construction, use and principle of the Sullivan galvanometer, with sketches.—*Duplex.*

Sullivan's Universal Galvanometer is a form of moving coil galvanometer for use at sea for testing and speaking purposes. Ordinary galvanometers require receiver-condensers for use on long cables in order to secure definite and legible signals, and to compensate retardation as much as possible. On short, well-insulated and comparatively non-inductive cables, practically the full impulses transmitted reach the distant end *at once;* but on long cables, owing to the retardation due to the electrostatic capacity and absorptive power of the insulating material surrounding the conductor (which retardation increases as the square of the length), the signals tail and lose their individuality, reaching the distant end more or less weak, sluggish and wavelike in character. To this retarding effect is superadded the inertia of the suspended coil in the case of ordinary galvanometers. The universal galvanometer possesses a sensibility which is high, and variable within wide limits; and it can be damped at will to absolute dead beatness. A general view of the Sullivan galvanometer, without cover, is shown in Fig. 1, and the suspended portion is shown in Fig. 2.

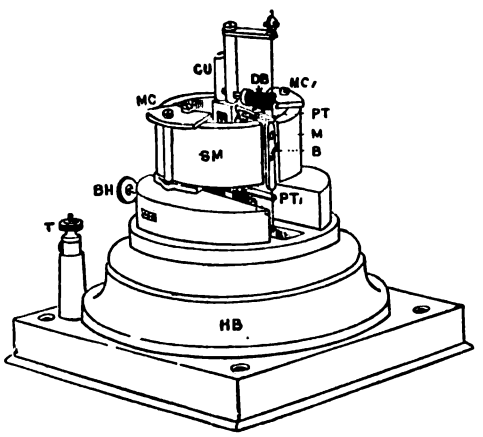

FIG. 1 (SULLIVAN GALVANOMETER).

The permanent steel magnet (S.M.) is C-shaped, and the suspended coil (C) is narrow and coreless, and is wound upon a metal frame. The suspension frame carrying the coil system is interchangeable, and a sleeve or tube (S), at its back, fits over a cylindrical upright (C U) planted upon a sliding base plate, which is movable forward and backward by means of a brass head (B H) projecting behind through the cover of the instrument. Thus by pushing or pulling the brass head, the position of the coil in the magnetic field, and, consequently, the sensibility of the instrument, may be varied without moving the cover. The coil is suspended from above, the upper torsion head (RT H) being in metallic connection with the suspension frame, whilst the lower torsion head (S T H) is insulated therefrom with vulcanite. The current is led to and from the coil through the suspension strips or wires and suspension rods (R and R), projecting from the coil, and the wires are in permanent connection through their torsion heads with two insulated platinum studs (P S and P S_1) on the lower arm of the suspension frame. These insulated studs are so placed that when the frame is pushed down into position they press upon two independent springs fixed in the hollow base (H B) of the instrument, and in permanent connection with the terminals (T). This dispenses with outside wire connections and allows the suspension frame to be rapidly changed when necessary. The coil ends are soldered to the rigid rods (R and R) projecting from it, and in order to prevent the coil from falling out and sustaining damage in case of breakage of the suspension, the frame is provided with two adjustable tongues (P T and P T_1), pierced at their ends with apertures through which these rods pass without touching. It will be seen that should the suspension break, the lower tongue takes the weight of the coil, thus holding it in position.

Two means of damping the swing of the coil are employed and applied simultaneously, the function and action of each being different. The first is the *electromagnet damping* due to the powerful opposing currents set up in the metal frame, on which the coil is wound, moving in the magnetic field of the permanent magnet. The second is due to the *mechanical* or *frictional damping* of two camel-hair brushes (D B) placed against the phosphor-bronze strip on which the coil is suspended, the effect of which—when the galvanometer is being used as a speaking instrument—opposes, as it were, a static friction, so that the coil does not start moving until the current has attained a certain value and produced sufficient turning moment; *i.e.*, the movement of the coil is retarded until the received impulse, or signal, or wave, has attained a value sufficient to give the coil a more or less rapid swing, so that the effect resembles a smart blow, and not a gradually increasing push, as

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would be the case without the camel-hair brushes.

These two effects are utilised to counteract each other to a certain extent ; *i.e.*, the electromagnetic sluggishness of the coil is atoned for by the mechanical or frictional damping. The electromagnetic damping tends to slow down the speed of the swing, but prevents the needle from swinging past its final position. Now, for ordinary testing purposes a large amount of electromagnetic damping is a distinct advantage ; for an extremely quick swing is not a necessity, as a slower and absolutely dead-beat deflection enables a quicker reading to be taken. But for telegraph signalling no reading of the amplitude of the swing has to be made, so that it is preferable to diminish the electromagnetic damping so as to accelerate the movement. This is simply done by cutting through the metal frame on its uppermost side and bridging it by a fine platinum wire, and the slightly increased resistance of the damping circuit is effective.

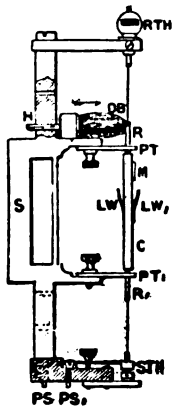

FIG. 2 (SULLIVAN GALVANOMETER).

GYROSTAT.—How does a system of three exactly similar gyrostats, of which the axes of rotation are at right angles to each other, behave to rotating couples ? How does the resistance offered depend on the velocity of rotation of the gyrostats ?

In its present form the question is too vague to admit a general answer. We require to know the manner in which the gyrostats are connected and supported before we can attack the question. The question might be solved by the general methods of rigid dynamics, but even the simplest case would require more space for discussion than we can afford. No general statement worth anything can be made, as some types of disturbance are consistent with stability, and others not. The term "resistance offered" to the disturbance is most pernicious and ambiguous.

DOT.—Two given circles intersect at O ; prove, by the method of inversion, that the inverse point of O with respect to any circle which touches them lies on one or other of two fixed circles which cut one another orthogonally.—*Cambridge Scholarship Papers* (*Cains group*).

Let A O B and C O D be any two lines cutting at O. The centres of all circles which touch both lines must lie on the bisectors of the angles at O. Hence the inverse point of O with respect to any of those circles must lie on one of the bisectors. If we invert with respect to any point we obtain the given problem, since A O B and C O D invert into circles, and the bisectors invert into two fixed circles cutting orthogonally. They intersect at the points of intersection of the given circles, and the tangents at the points of intersection bisect the angles between the tangents to the given circles at the points of intersection.

POLYGON.—Find the maximum stress in an element subjected to a shear combined with a tension at right angles to it.

We are not aware of any principle by which a shearing stress can be replaced by a single tensile stress. Moreover, stresses cannot be compounded in the same manner as forces.

The matter is best considered by aid of the stress quadric

$$P x^2 + Q y^2 + R z^2 + 2 (S yz + T zx + U xy) - 1 = 0,$$

where P, Q, R, S, T, U are the components of stress in the usual notation.* In the special case of a single tensile stress and a single shearing stress, we may take

$$P x^2 + 2 U xy = 1$$

as the stress quadric. Rotating the axis through an angle θ given by $\tan 2\theta = \frac{2U}{P}$, we obtain

$$\left(\frac{P}{2} + \sqrt{\frac{P^2}{4} + U^2} \right) x^2 + \frac{P}{2} y^2 = 1$$

as the stress quadric.

Thence the maximum stress is

$$\frac{P}{2} + \sqrt{\frac{P^2}{4} + U^2}$$

CARRIG.—Can you inform me of the formula for chrome-tanned leather, used in uppers of boots and shoes.

The precise formula of chrome tanned upper leather varies with the details in the method of its production. The variation includes some difference in the proportion of sulphur deposited in the fibres of the pelt. Upper leather is generally made from ox, calf, horse, or goat skin. The percentage composition of these are :—

Ox, calf, and horse, C 50·2, H 6·4, N 17·8, O 25·4.

Goat, C 50·3, H 6·4, N 17·4, O 25·9.

The structure of animal skin is either identical with gelatin, or only differs in the molecular condition of the white fibres, or degree of hydration. The percentage composition of gelatin is C 40·7, H 6·8, N 18·3, O 25·2. This gives the formula as $C_{76} H_{124} N_{24} O_{29}$. Chrome tanning by the Shultz method is based upon the reduction of free chromic acid upon the fibres of the skin. This is achieved in two processes or "baths." The first bath consists of a solution of potassium dichromate and hydrochloric acid ($K_2 Cr_2 O_7 + HCl$). The proportions usual are 2·5 parts of HCl to 5·0 parts of dichromate ; reckoned on the wet weight of the pelt. The following formula gives the reaction in the first bath :—

$$K_2 Cr_2 O_7 + 2HCl = 2KCl + 2Cr O3 + OH_2.$$

The quantity of water used for solution is about 300 per cent. The second, or

* See Thomson and Tait. Vol. ii., p. 207.

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"reducing" bath consists of HCl and "hypo-soda" ($Na_2 S_2 O_3$); the character of the finished leather being influenced by the proportion of the HCl used; the density of the leather being in proportion to the deposit of sulphur. These reactions are shown in the following equations:—

(1) $6Cr O_3 + 2HCl + 12Na_2 S_2 O_3 = 6Na_2 S_4 O_6 + 12 Na Cl + 6o H_2 + 2Cr_3 O_6$

(2) $4Cr O_3 + 12HCl + 6Na_2 S_2 O_3 = 6Na_2 S O_4 + 6S + 4Cr Cl 6o H_2$.

The solution in the second bath is in the proportion of 12 parts of hypo to 6 parts of hydrochloric acid in 400 parts of water. These proportions have to be varied in practice, according to the condition of the pelt and the character desired in the finished leather. As a rule, the first bath should have an excess of either acid or dichromate; it does not appear to be very important which, although it affects the details of the second bath. If the first bath has an excess of acid the second bath may be prepared without acid, that being added in small quantities, until the character required in the leather has been obtained.

EXMOUTH.—A weight of 1lb. is suspended by a spiral spring from an arm that is attached to a heavy base. This apparatus is stood on a place subject to vibration, such as a suspension bridge. The original length of the spring is (say) 1 inch; and the length to which it is stretched when carrying a weight of 1lb. is (say) 2 inches.

Can I calculate the actual movement of the bridge, etc., by measuring the (apparent) movement of the suspended weight? If the apparatus was placed on the top of an engine, could I determine the amount of the unbalanced forces?

In order that the *apparent* motion of the suspended weight shall be equal to the *true* motion of the bridge, the weight must remain practically at rest. The conditions necessary for this can be determined as follows. The motion of the bridge will alternately elongate and shorten the suspending spring, and these actions will tend to set the weight oscillating. If the period of oscillation of the weight is very long, then an oscillation in one direction, due to (say) the tension of the spring, will hardly have commenced before the spring shortens, the tendency then being to set the weight in motion in the opposite direction. Thus the weight will remain practically stationary if its period of oscillation is very long in comparison with the period of the vibrations to be investigated.

If a weight M_1 lbs. elongates a spring through 1 ft., then the period of oscillation of a weight of M lbs., suspended from the spring, will be equal to

$$T = 2\pi\sqrt{\frac{M}{M_1 g}}$$

In the case quoted above, M = 1lb., while M_1 = 12lbs. Then

$$T = 2\pi\sqrt{\frac{1}{12 \times 32}} = 0{\cdot}32 \text{ sec.}$$

Thus the weight would perform about 3 free oscillations per second. If the oscillations to be measured were much more rapid than this, (*i.e.*, about 300 per second), the above arrangement would be satisfactory. Otherwise it would be necessary to hang a larger weight from a longer and weaker spring, so as to obtain a system vibrating in a much longer natural period.

The stand carrying the weight should be bolted or rigidly attached to the bridge, and not merely stood on it. If it were fixed to the top of an engine, the magnitude of the vibrations of the engine could be measured by its aid, but not the stresses producing these vibrations.

ENDEAVOURER.—Five ladies, each accompanied by her daughter, purchased cloth at the same shop. Each of the ten bought as many feet of cloth as she paid farthings per foot. Each mother spent 8s. 5½d. more than her daughter. Mrs. Robinson spent 6s. more than Mrs. Evans, who only spent about a quarter of what Mrs. Jones did, while Mrs. Smith spent most of all. Mrs. Brown bought 21 yards more than did Bessie, one of the girls, while of the other girls, Annie bought 16 yards more than Mary, and spent £3 0s. 8d. more than Emily. The other girl's christian name was Ada; what was her surname?—*Tutorial Arithmetic, by W. P. Workman.*

The key to the solution lies in the fact that, whatever the number of feet of cloth a lady buys, she must spend in farthings a number equal to the square of the number of feet. This result is easily seen, for if a lady buys 10 feet of cloth, each foot must cost 10 farthings, and the total cost must, therefore, be 10^2 farthings. Hence the expenditure in farthings of each lady must be a perfect square.

Mrs. Evans buys a certain number of feet and spends that number squared in farthings.

Miss Evans spends that number squared, minus 405.

Miss Robinson spends the same number squared, minus 117. For Mrs. Robinson spends 288 farthings more than Mrs. Evans, and since each daughter spends 405 farthings less than her mother, it follows that Miss Evans spent 405 − 288 = 117 farthings less than Mrs. Evans. The expenditure of both daughters must be perfect squares, and hence 405 and 117 must each be the difference between two squares, the larger square being the same in both cases. By trial we see this common square may be 21^2, or 11^2 in the first case, and 21^2 in the second; hence 21 feet is the amount of cloth Mrs. Evans bought.

We have now the following tale:—

Mrs. Evans	buys 21 ft.	and spends	441	farthings
Miss Evans	„ 6 ft.	„	36	„
Mrs. Robinson	„ 27 ft.	„	729	„
Miss „	„ 18 ft.	„	324	„
Mrs. Jones	„ 42 ft.	„	1,764	„ (about)
Miss Jones	„ 37 ft.	„	1,369	„ (about)

Mrs. Brown buys 63 feet more than Bessie; let us see if Bessie can possibly be either Miss Evans, Robinson or Jones. If Bessie is Miss Evans, then

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Mrs. Brown buys 69 feet and spends 4,761 farthings
Miss Brown buys 66 feet and spends 4,356 farthings.

As 4,356 is a perfect square, this guess is probably correct. Similarly we can show that Bessie *cannot* be Miss Robinson.

We are also given that Annie spends more than Mary and Emily, hence Annie must be either Miss Brown or Miss Smith. Since no exact information is given about Mrs. Smith, we try if Annie can be Miss Brown. Annie buys 48 feet more than Mary, and spends 2,912 farthings more than Emily. On referring to the results already obtained we see that $66-48=18$ must refer to Miss Robinson, and $4,356-2,912=1,444$ must refer to Miss Jones. Hence Mary is Miss Robinson, and Emily is Miss Jones. Finally, Ada must be Miss Smith.

ENGINEER.—Give a graphical representation of the relative motion of a piston and crank when the connecting rod is long enough for its obliquity to be neglected; and prove that at R revolutions per minute, the piston velocity is $\frac{\pi R}{30}$ times the geometric mean of the distances from the piston to the two ends of the stroke. Prove that if the piston weighs W lbs., the force in pounds which gives its acceleration is

$$\frac{W}{g}\cdot\frac{\pi^2 R^2}{900}\times \{\text{Distance in feet from mid-point of stroke.}\}$$

London University, Inter. B.Sc. Engineering, 1903.

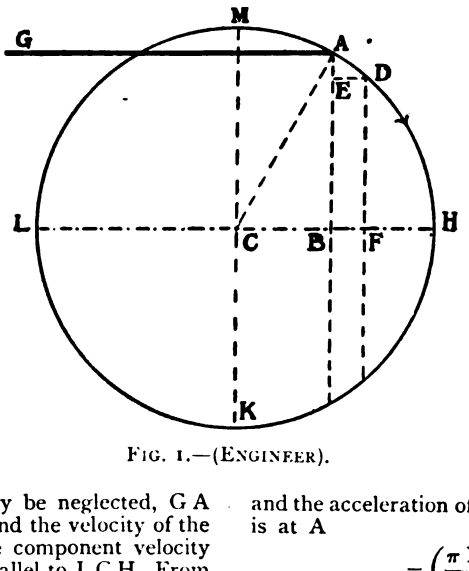

FIG. 1.—(ENGINEER).

Let G A, (Fig. 1) be the connecting rod, the end A (attached to the crank) moving round the circle A H K L M. Since the connecting rod is long, and its obliquity may be neglected, G A will be parallel to L C H, and the velocity of the piston will be equal to the component velocity of the point A, resolved parallel to L C H. From A draw A B perpendicular to C H; let $C A = r$, and let the point A complete n revolutions per second. Then the linear velocity of the point A is uniform, and equal to $2\pi n r$. In a small interval of time t, let the point A move from A to D. From D draw D E perpendicular to A B. Then we may treat the small arc A D as a straight line of length $2\pi n r t$. During the same interval of time the piston moves through a distance E D, and its velocity is equal to E D/t. Since A D is perpendicular to A C, and E D is perpendicular to C M, the angles A D E and A C M are equal. Then

$$\begin{aligned} E D &= A D \cos A D E \\ &= A D \cos A C M \\ &= A D \sin A C B = 2\pi n t . r \sin A C B \\ &= 2\pi n t . B A \end{aligned}$$

∴ Component velocity of A, resolved parallel to L C H = E D/t

$$= 2\pi n . B A.$$

Now $(B A)^2 = L B \times B H$; therefore B A is the geometric mean between L B and B H, *i.e.*, the geometric mean between the distances from the piston to the two ends of the stroke. Also $n = R/60$, so that the velocity of the piston when the crank is at A

$$= 2\pi\left(\frac{R}{60}\right) B A = \frac{\pi R}{30} \times B A.$$

The force, in poundals, which is necessary to produce the acceleration of the piston, is equal to the mass of the piston multiplied by its rate of increase of velocity. Now when the crank is at A, the velocity of the piston is equal to

$$\frac{\pi R}{30} \times B A.$$

After t seconds the crank will reach B, when the velocity of the piston will be equal to

$$\frac{\pi R}{30} \times F D$$

where F D is the perpendicular distance from D to the line C H. Hence the *acceleration* of the piston when the crank is at A is equal to

$$\frac{\frac{\pi R}{30}\left(B A - F D\right)}{t} = \frac{\pi R}{30}\cdot\frac{E A}{t}$$

But E A
$= A D \sin A D E$
$= 2\pi n t . r \cos A C B$
$= 2\pi n t . C B$
∴ E A/t
$= 2\pi n . C B = \frac{\pi R}{30} . C B,$

and the acceleration of the piston, when the crank is at A

$$= \left(\frac{\pi R}{30}\right)^2 . C B,$$

where C B is the distance of the piston from the mid-point of its stroke. If we multiply this quantity by W, the mass of the piston, we obtain the force producing its acceleration, measured in *poundals;* on dividing by g (the force exerted by gravity on a mass of one pound), we obtain the force in pounds.

POLYGON.—Given a succession of observed values for x and y, which are known to follow the law

$$y = \frac{a x}{1 + s x},$$

how can the values of a and s be found?

Let y_1, x_1, be corresponding values of y and x; while y_2, x_2 are another pair of values of these quantities. Then, substituting in the above formula, and transforming, we obtain

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$$a = \frac{y_1 + s x_1 y_1}{x_1} \quad \ldots\ldots\ldots (1)$$

$$\text{Also } a = \frac{y_2 + s x_2 y_2}{x_2} \quad \ldots\ldots\ldots (2)$$

$$\therefore \frac{y_1 + s x_1 y_1}{x_1} = \frac{y_2 + s x_2 y_2}{x_2}$$

$$y_1 x_2 - y_2 x_1 = s(x_2 y_2 - x_1 y_1)$$

$$\therefore s = \frac{y_1 x_2 - y_2 x_1}{x_2 y_2 - x_1 y_1}$$

Substitute this value of s in (1), and the value of a becomes known.

CROSSHEAD.—On a piston, of 120 sq. inches area, and weighing 290lbs., there is at a certain instant a pressure of 130lbs. per sq. inch on one side more than on the other. If the piston acceleration at that instant is 420 ft. per second per second in the direction in which the steam is urging the piston; what is the total force acting on the cross-head?

If this acceleration occurs when the piston is one quarter of its stroke from one end: assuming an infinitely long connecting rod, how many revolutions per minute is the engine making?

Net force due to steam pressure on piston $= 120 \times 130 = 15{,}600$ lbs. Now a resultant force of 1 lb., acting on a mass of 1 lb., would produce an acceleration of 32ft./sec^2. Thus the resultant force that must act on a mass of 290lbs. in order to produce an acceleration of 420 ft./sec^2. must be equal to

$$\frac{1 \times 420 \times 290}{32} = 3{,}807 \text{ lbs.}$$

Thus force acting on cross-head $= 15{,}600 - 3{,}807 = 11{,}793$ lbs.

Let r be the radius, in ft., of the circle described by the crank. Then, with an infinitely long connecting rod, and a uniform rate of rotation of n turns per second, the acceleration of the piston at one quarter of a stroke from an end, will be equal to

$$r \times (2\pi n)^2 \cos\theta$$

where θ is the angle that the crank has turned through from the beginning of the stroke. (See answer to *Engineer*.) Now since the connecting rod is infinitely long, $2r$ will be equal to the stroke of the engine; and since one quarter of the stroke has been performed,

$$\cos\theta = \frac{(1 - \frac{1}{2})r}{r} = \frac{1}{2}$$

$$\therefore n = \frac{1}{2\pi}\sqrt{\frac{420}{r \times \frac{1}{2}}}$$

The value of n cannot be computed unless r is known.

ALPHA.—Find the value of

$$I = \int_0^{\frac{\pi}{2}} \tan x \log \sin x \, dx.$$

Let $\log \sin x = u$, then $\sin x = e^u$, and

$$I = \int_{-\infty}^{0} \frac{u e^{2u}}{1 - e^{2u}} du$$

$$= \int_{-\infty}^{0} u e^{2u} \left(1 + e^{2u} + e^{4u} + \ldots\right) du$$

$$\text{Now } \int u e^{2nu} du = \frac{1}{2n} u e^{2nu} - \frac{1}{2n}\int e^{2nu} du$$

$$= \frac{e^{2nu}}{2n}\left(u - \frac{1}{2n}\right)$$

By finding the limiting value of $u e^{2nu}$, when $u = -\infty$, we have

$$\int_{-\infty}^{0} u e^{2nu} du = -\frac{1}{4n^2}$$

$$\text{Hence, } I = -\left(\frac{1}{2^2} + \frac{1}{4^2} + \frac{1}{6^2} + \ldots\right)$$

$$= -\frac{\pi^2}{24} \quad \left(\begin{matrix}\text{Todhunter's Trig., Ch. xxiii. Lock's}\\ \text{Higher Trig., Ch. vi.}\end{matrix}\right)$$

STUDENT A.—Integrate in series or by other means

$$\frac{dx}{a x^n - b x^2 - c x} = dy$$

a, b and c are constants, and $x = 0$ when $y = 0$; n is greater than 1, and may or may not be greater than 2.

$$\frac{1}{a x^n - b x^2 - c x} = \frac{A}{x} + \frac{B x^{n-2} + C}{a x^{n-1} - b x - c}$$

From which we easily find $A = -\frac{1}{c}$,

$B = \frac{a}{c}$, $C = -\frac{b}{c}$, and hence

$$y = \int_0^x \frac{dx}{x} + \frac{1}{c}\int_0^x \frac{a x^{n-2} - b}{a x^{n-1} - b x - c} dx.$$

The first integral gives $\log x - \log 0$, and is, therefore, equal to $-\infty$, and it is obvious that the second one is finite for many positive integral values of n, *e.g.*, $n = 2$, $n = 3$, and also for many fractional values of n, *e.g.*, for $n = \frac{3}{2}$ the integral becomes

$$\int_0^{\sqrt{z}} \frac{a - bz}{a z - b z^2 - c} dz$$

which is finite in general. Hence no general finite expression can be found for the integral. From the given value of $\frac{dy}{dx}$, it is seen that $\frac{dy}{dx}$ is ∞ for $x = 0$, and since $y = 0$ for $x = 0$ the axis of y must be tangent, and hence $y^m = f(x)$ where $m = 2$ or greater than 2.

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$x = B - B\cos ay \quad \frac{\phi}{2} + \frac{}{2} \quad \frac{}{3a^2} \quad \frac{}{2D} \quad \frac{}{3a^2} \quad \frac{}{2D}$

$= B - (B + \frac{1}{2}a^2 y)\cos ay + \frac{AB^2}{2a}\left(\frac{\sin 2ay}{3a^2} + \frac{a}{D}\cdot\frac{\cos 2ay}{3a^2} + \frac{a}{2D}\right)$

CALCULUS.—Find the value of the indefinite integral

$$\int (1+x)^{\frac{1}{2}}\, dx$$

This is a perfectly straightforward integration.

Let $1 + x = z$

$dx = dz$

$$\int (1+x)^{\frac{1}{2}}\, dx = \int z^{\frac{1}{2}}\, dz = \tfrac{2}{3} z^{\frac{3}{2}} = \tfrac{2}{3}(1+x)^{\frac{3}{2}}$$

This integral is not, as you state, the one that occurs in obtaining the length of the arc of a parabola.

Thermo :—From the equations

$$\frac{dz}{dy} = A\,(B - x - z)\,(C - z) \quad (1)$$

$$\frac{dx}{dy} = Dz \quad \ldots\ldots\ldots \quad (2)$$

express x in terms of y, ~~given that A and B are small compared to C and D,~~ given also the initial conditions, *viz.*, both x and z zero when $y = o$.

From (2) we obtain

$$\frac{d^2x}{dy^2} = D\frac{dz}{dy} \quad \ldots\ldots \quad (3)$$

Multiplying (1) out and substituting from (2) and (3) we obtain

$$\frac{1}{D}\frac{d^2x}{dy^2} = \frac{A}{D^2}\left(\frac{dx}{dy}\right)^2 + \frac{A}{D}(x - B - C)\frac{dx}{dy} + AC(B - x)$$

As a first approximation, neglect $\frac{A}{D^2}$ and $\frac{A}{D}$ in comparison with A C, solve the resulting equation and substitute the solution in the terms previously neglected, and solve the new equation. The method is known as that of *successive approximation*.

As a first approximation we have

$$\frac{d^2x}{dy^2} + A\,C\,D\,(x - B) = c$$

$$\text{or } \frac{d^2(x-B)}{dy^2} + a^2(x-B) = o \left\{\begin{matrix}\text{the simple harmonic}\\ \text{motion equation.}\end{matrix}\right.$$

where $a^2 = A\,C\,D$.

Hence $x - B = K_1 \cos ay + K_2 \sin ay$

and $\frac{d(x-B)}{dy} = (-aK_1 \sin ay + aK_2 \cos ay) = Dz$. But when $y = o$, $x = o$; and $z = o$.

Hence $-B = K_1$

$o = K_2$

and $x - B = -B\cos ay$.

From this we have $\frac{dx}{dy} = aB\sin ay$, and hence our second approximate equation is

$$\frac{d^2x}{dy^2} + a^2(x-B) = -A\,(B\cos ay - C)\,aB\sin ay$$

$$+ \frac{A}{D}a^2B^2\sin^2 ay$$

$$= a^3 \sin ay, -\frac{aAB^2}{2}\sin 2ay + \frac{A}{2D}a^2B^2(1 - \cos 2ay).$$

A particular solution P of this is easily obtained by the symbolic operator method :

$$P = a^3 \frac{\sin ay}{\Delta^2 + a^2} + \&c. \left(\text{where } \Delta = \frac{d}{dy}\right)$$

The first term is the only one offering any difficulty ; it is worked as follows :—

$$\frac{a^3}{2i}\frac{e^{yai} - e^{-yai}}{(\Delta + ai)(\Delta - ai)} = \frac{a^3}{2i}\left\{e^{yai}\frac{1}{\Delta(\Delta + 2ai)} - e^{-aiy}\frac{1}{\Delta(\Delta - 2ai)}\right\}$$

$$= \frac{a^3}{2i}\left\{\frac{e^{aiy}}{2ai}y + \frac{e^{-aiy}}{2ai}y\right\}$$

$$= -\frac{a^2}{2}y\cos ay.$$

Hence

$$P = -\frac{a^2 y\cos ay}{2} + \frac{aAB^2}{2}\frac{\sin 2ay}{3a^2} + \frac{Aa^2B^2}{2D}\frac{\cos 2ay}{3a^2} + \frac{AB^2}{2D}$$

and the total approximate solution is

$$x - B = -B\cos ay + P.$$

The constants being determined as before.

L.A.D.—A model M_1, 10 ft. 1½ ins. long, was made of a ship S_1 243 ft. in length ; together with a model M_2, 10 ft. 11¼ ins. long, of a ship S_2, 262 ft. 5 ins. in length.

The wetted surfaces of S_1 and M_1 are 8·661 sq. ft. and 15·034 sq. ft. respectively ; while the wetted surfaces of S_2 and M_2 were 10·120 sq. ft. and 16·288 sq. ft. respectively.

The models are towed from the two extremities of a beam fitted to the bow of a launch, with suitable attachments, at a speed of 5·694 statute miles per hour in fresh water, and the fulcrum so adjusted that they run evenly (or balance). When this is done, the length of the arm, from fulcrum to attachment for M_1 is 10·39 ft., and from fulcrum to attachment for M_2 is 13·25 ft.

(1) Knowing the I.H.P. to be 3,593 at 16·7 statute miles per hour with S_1 ; how can I calculate the I.H.P for any other speed for S_2 ?

(2) Could this result be obtained direct from the towing trial, if the resistance is measured ; and what corrections are necessary in passing from a model in fresh to one in salt water?

(3) How can I calculate the resistance due to (*a*) skin friction and (*b*) residuary resistance, of these models ; and how can I apply this to the case of the ship?

(1) This question depends on applying Froude's Law of Comparison to a ship and its model, for the residuary resistance. The question appears wrongly stated, as the model M_1, and the ship S_1, are not being run at "corresponding speeds," which is necessary in order that the law of comparison may be used. The rate of scale is $243 \div 10{\cdot}125 = 24$, and the speed of model "corresponding" to 16·7 miles per hour of ship should have been $16{\cdot}7 \div \sqrt{24} = 3{\cdot}4$ miles per hour, and not 5·694 miles per hour, as stated.

The ship requires 3,593 i.h.p. for 16·7 miles. Assuming a propulsive coefficient of 0·5, the effective h.p. of ship is 1,796. This is used in overcoming the resistance, which is made up of

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two parts, *viz.* : frictional F_1, and wave-making or residuary W_1. The part F_1 is obtained by calculation from the known wetted surface, and so W_1 can be found by subtraction. By the law of comparison the residuary resistance of model M_1 is at once found; $W_1 \div (24)^{3/2} = W_1$ (say) at the corresponding speed 3·4 miles. The frictional, f_1, of model can be calculated by using appropriate coefficients, and so the total resistance of model, $M_1 = f_1 + w_1$ is found. Now, by towing the models abreast, as stated, the total resistance of model M_2 is $(f_1 + w_1) \times \frac{10{\cdot}39}{13{\cdot}25}$.

The object of the whole experiment is to find the i.h.p. for the ship S_2 (of length 262′5″) at some definite speed (which is not stated). For this speed (V_2 say), the model M_2 must be of such a size that V_2 and 3·4 knots obtained above "correspond" for the ship and model. What we want first to find is the total resistance of ship S_2 at speed V_2. We can readily calculate the frictional F_2; we therefore want the residuary W_2. Now, from model M_2 we found above the total resistance, and calculating the frictional resistance, we can find the residuary w_2, say. This can be at once converted into W_2 by using the law of comparison. We thus have the resistance of ship S_2 at speed V_2, *viz.* : $F_2 + W_2$. This resistance is at once converted into effective h.p., using the same propulsive coefficient as before; *viz.* : 0·5 into i.h.p.

(2) By delicate apparatus the total resistance of model could be obtained. This is done in the experiment tanks at Haslar, etc. The method described in question does not depend on such delicate methods of measurement. A full description was given by Col. English before the Institute of Mechanical Engineers some years back. It is reproduced in a book on "Resistance of Ships," by Atherton & Wellanby, recently published at Manchester (5*s.* net).

(3) The answer to this question would require much space, and would only be a repetition of what can be found in various text-books on the subject, as for instance, the one mentioned above.

This question has not been worked out numerically, because of the manifestly incorrect data supplied; and the most important speed, *viz.* : that for the ship S_2, for which the indicated i.h.p. is required, not being stated. It is rather a big order to "calculate the indicated i.h.p. for any other speed for S_2." The speed required for S_2 must be the starting-point of the problem.

STUDENT.—If a ship is on trial over a measured mile, at a time of tide when the speed of the ship is increasing or decreasing at a practically constant rate, show that the Admiralty rule of taking the mean of the means of every two consecutive runs eliminates the tidal error; and show also what this indicates as to the proper carrying out of speed trials under that rule, and as to the limits of its application.—*Board of Education, Naval Architecture, Hon. II.*, 1901.

The speed of tide, increasing or diminishing at a constant rate, can be written $v = v_0 + at$, where v_0 is speed at some given time, a is a constant, and t is the time. Therefore the speed of tide at equal intervals of time t will be $(v_1 = v_0 + at)$; $(v_2 = v_0 + 2at)$; $(v_3 = v_0 + 3at)$; $(v_4 = v_0 + 4at)$.

If at these equal intervals of time, a ship, whose true speed over the ground is V_0, goes up and down the mile, the observed speeds will be

$V_0 + v_1$, $V_0 - v_2$, $V_0 + v_3$, $V_0 - v_4$, etc.,
or $(V_0 + v_0 + at)$, $(V_0 - v_0 - 2at)$,
$(V_0 + v_0 + 3at)$, $(V_0 - v_0 - 4at)$, etc.

The ordinary mean of these speeds gives $V_0 - \frac{1}{2}at$, there being an error of $\frac{1}{2}at$. With the "mean of means" we get the following :—

Observed Speed.	1st Means ×3	2nd Means ×4
$V_0 + v_0 + at$ $V_0 - v_0 - 2at$	$2V_0 - at$	$4V_0$
$V_0 + v_0 + 3at$ $V_0 - v_0 - 4at$	$2V_0 + at$ $2V_0 - at$	$4V_0$

Thus the mean of the means gives us the true mean speed V_0 as required.

The same thing is true if six runs are taken, and so on. It can be shown more generally that if the speed of tide is expressed as a quadratic function of the time, *viz.*:— $v = x_0 + at + bt^2$, the error involved in taking the "mean of means" is exceedingly small.

The above investigation shows that the mile should be run at equal intervals of time, and over the same course for all the runs. If a long sweep were made between the 2nd and 3rd runs, it would be found that the "mean of means" would give too great a result. The speed of tide will vary at different places, and if Nos. 2 and 4 against the tide were run in shore where tide was slack, and 1 and 3 where tide was full, an excess would also be obtained over the true speed.

EQUIPMENT OF WORKSHOP.—I am thinking of equipping a small engineering workshop for general purposes, largely for repair work. I intend to fit it with a few lathes, one or two shaping and planing machines, a slotting machine, and such milling machines and capstan lathes as my purse will from time to time permit. Above all, I want the whole scheme to be thoroughly modern in driving power, and on this point I am variously advised. Many urge me to relinquish the steam engine in favour of petroleum, but the failures and troubles of oil engines deter me, and I think I could compromise by the use of gas, of which there is a supply. The steam engine would seem to be more trustworthy, however; but here again I am in trouble as to choice, for while some friends advise a high-speed engine and dynamo, with electric distributors, others (and these I confess myself inclined to follow, because of my doubt and insufficient knowledge) still advocate the older slow-speed engine with shafting and belting. Finding that it is difficult to obtain definite advice founded on trustworthy data, I appeal to the kindness of the readers of "Technics," and shall be greatly obliged if any of these can oblige me with information

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regarding the founding of such a shop as I have suggested, giving, if possible, a comparison of the various systems as regards first cost, upkeep in repairs, wages bill, and liability to failure in the hands of ordinary workmen. I may mention that there is no central electric station near, from which I could buy electricity.

* Comparing the recommendations of the correspondents, after rejecting a few whose estimates were either too low or too high, we have :

Machine Tools Recommended.

4 lathes : 16" to 6".	2 capstan lathes.
1 planer.	1 grindstone.
1 shaper.	1 emery wheel.
2 drills (radial and pillar).	1 boring machine.
	1 circular saw.
1 slotter.	1 band saw.
1 milling machine.	1 wood lathe.

In addition, a smithy of two fires, and a small plating shop are advised. No mention of a steam hammer is made (though advisable), while a foundry is unanimously vetoed.

Cost of plant about £900. Total cost of workshop and plant about £3,000.

The brake horse-power varied from 10 up to 50. It is needless to say that an engine of 20-h.p. is more than ample for the purposes.

DRIVING POWER.

Comparison of first costs, including erection ; working costs per annum with fuel, and repairs per annum :—

	First cost.	Working cost.	Repairs.	Int. and deprec.
Steam engine : slow speed, direct . .	£300	£100	£10	£34
Gas engine : lighting gas . . .	£150	£100	£5	£20
Oil engine : heavy oil. . . .	£220	£100	£5	£27
Steam engine : high speed, and elec. distbn.	£500	£75	£7	£50

The first cost of shafting may be taken at £60.

COMPARATIVE ADVANTAGES OF THE SYSTEMS.

ADVANTAGES.	DISADVANTAGES.
Steam Engine, Direct.	
Economical at full load.	Uneconomical at light load.
Cheap working in coal district.	Expensive in attention
Steady torque under varying loads.	First cost heavy.
Little liability to breakdowns ; and may be repaired at night.	Cost of cleaning boiler.
	Much space required, *e.g.*, coal storage.
Easy to purchase second-hand.	Slow at starting (boiler).
Steam Engine Direct—(continued).	
Steam useful for hammer and shop warming.	Depreciates rapidly.
Gas Engine (lighting gas).	
Cheap in first cost.	Depends on gas supply, but gas strike unlikely.
Upkeep low with 3s. gas.	
No attendance required.	Breakdowns entirely stop the work.
No storage of fuel.	No heat to shops.
Starts quickly.	Noise.
Little space occupied.	
No chimney.	
Easy to purchase second-hand.	
Oil Engine.	
Price of oil does not vary as to district.	Breakdowns stop the work.
Non-dependent on central supply.	Smell.
	Noise.
Cheap fuel.	Storage space required
No attendance.	No heat to shops.
Starts quickly.	
No chimney.	
Steam Engine with Electric Distribution.	
Very convenient distribution.	Great first cost, and insufficient return.
Flexible leads.	Skilled engineers required.
Failure unlikely.	
Economy in distribution.	Repairs by outside men.
Lighting of shops.	

* Answer compiled from papers submitted for "Open Query" Competition, January *Technics*, pp. 101.

FINAL NUMERICAL COMPARISONS.

	Fuel.	Working costs, with interest, etc	Liability to breakdown.
Steam direct . . .	2·52	134	1
Gas	3·56	115	1¼
Oil	3·45	122	1½
Electric distribution	2·72	122	1¼

Steam direct is advised if the shop is somewhat large, but gas is more economical, even when its price is so high as 3s. 6d. per 1,000 c.ft., and is always advised in preference to oil, which is looked upon as unreliable, and voted generally as a nuisance. One competitor must be mentioned, who plumps most decisively for petrol, quoting what are known as its "Reliability trials" : it is most probable that he is largely right in his choice. Electric distribution is said to be quite out of the question for a small shop, and a consideration of the figures entirely supports the decision. Special conditions must always have weight, such as the range and rapidity of variations of the load, but nearly all agree that the querist had better instal a gas engine.

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"TECHNICS" COMPETITIONS.

A GOLD MEDAL and £200

To be awarded Annually to the "Technics" Prizeman.

£50 IN PRIZES OFFERED IN THIS ISSUE.

PARTICULARS of 51 competitions have been given in the January, February, March, and April numbers of "Technics."

The present number contains particulars of 15 competitions, for which money prizes amounting, in the aggregate, to £50 will be awarded.

At the end of the year, a prize of £200 in cash, and a Gold Medal, will be awarded to the competitor who has shown the most care, thought, and accuracy in the year's competitions.

£50 IN PRIZES.

General Rules.

Competitors are requested to note the following rules:—

All writing must be on foolscap paper. Only one side to be written upon, and a reasonable margin left.

Competitors should see that their drawings are sent either rolled or flat—flat preferred. They must not be creased. They must also be executed in black ink.

N.B.—All drawings, and each page of MS., must bear a *nom-de-plume*, and must be accompanied by a closed envelope containing the name and address of the Competitor. The outside of the envelope must bear the Competitor's *nom-de-plume* only. *This rule does not apply to homework competitions.*

The Editors reserve the right to publish, without further payment, contributions that gain prizes. Should any article or drawing that has not gained a prize be published in the magazine, payment will be made at the usual rate.

Should the best answer in any competition be deemed of insufficient merit, the Editors reserve the right to withhold the prize.

All competitions must be addressed to the Competition Department, "Technics," 3 to 7, Southampton Street, Strand, W.C., and must reach these offices not later than June 10th. Results will be published as soon as possible.

In each case the work will be submitted to an expert competent to declare which is the best practical suggestion, design, or article.

COMPETITIONS.

QUESTIONS ON MOTOR CARS.

£5 prize for best set of answers.

1. Explain precisely the function of the fins attached to radiators of the Loyal pattern.
2. Discuss in detail the relative advantages and disadvantages of the radiators of the Loyal and Honeycomb types.
3. Give a detailed account of the function of the fly-wheel.
4. Give a detailed discussion of the relative advantages and disadvantages of the chain and the live axle drive.

QUESTIONS ON THEORY OF STRUCTURAL DESIGN.

£5 prize for best set of answers.

1. State clearly, concisely, and in your own words, why the term "moment of inertia" is objectionable when used in beam and column formulæ.

2. What is the "theorem of parallel axes?" Give an example of its use.

3. Show how the value of I may be obtained for a rolled steel joist, when we know that the value of I for a rectangle $= \frac{1}{12}bd^3$. The tapering of the flanges and the rounding of the corners need not be taken into account.

In the first instance, assume that the axis passes through the centre of gravity of the beam, and is parallel to the flanges. In the second instance, assume that the axis is coincident with the

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centre line of the web, *i.e.*, as though the joist were laid on its side to carry the load. Illustrate your method by sketches, and give your calculations for a rolled steel joist 20 inches × 7½ inches, with web assumed at § inch thick and non-taper flanges 1 inch thick.

4. Give a brief synopsis, in a series of numbered paragraphs, of the chain of reasoning used in Part V. of the "Theory of Structural Design." Your answer must be limited to 500 words.

QUESTIONS ON MOTOR STARTING RESISTANCES.

£5 prize for best set of answers.

1. Criticise the motor starting resistance represented in Fig. 1, p. 470. If you can, suggest a possible improvement in its construction.

2. A five horse-power motor is to be run on a 100-volt circuit: efficiency of motor at full load = 80 per cent. Calculate the resistance in each of the various sections of a rheostat to be used to start this motor at full load. (Armature Resistance = 0·3 ohms.)

3. Specify the dimensions, etc., of the wire used in constructing the resistance required in Question 2.

4. Give the full design for the starting rheostat required in Question 2.

QUESTION ON DYNAMO COMMUTATION.

£2 prize for best answer.

The magnetic field due to the current in a particular armature section is associated with a certain amount of energy. When this section is short-circuited during commutation, the current must fall to zero, and then increase in the opposite direction, to a value numerically equal to that which it originally possessed. As the current falls to zero, the energy of the magnetic field is reduced to zero; as the current increases in the opposite direction extra energy must be supplied to produce the magnetic field. What becomes of the energy which disappears (1) when commutation is performed by the aid of metal brushes which are given a suitable lead in order to secure sparkless running; (2) when fixed carbon brushes are used?

QUESTION ON BOOT AND SHOE MANUFACTURE.

£3 prize for best answer.

Describe a practical application which you have made of the principles explained in Mr. Swaysland's article on the Manufacture of Boots and Shoes.

QUESTION ON HOW TO SET THE ROLLERS IN COTTON MACHINERY.

£3 prize for best answer.

Discuss the diagrams given in Mr. Scott Taggart's article. Explain their precise meaning, and give one or two examples of their use.

QUESTION ON POTTERS' MATERIALS.

£3 prize for best answer.

Describe how the principles dealt with in Mr. Rix's article are utilised in the pottery trade.

QUESTION ON PAPER MANUFACTURE.

£3 prize for best answer.

Describe the method of coating and glazing an art paper, to be specially suitable for an illustrated magazine.

HOMEWORK COMPETITIONS.

A prize of £3 will be awarded for the best Homework Book, or set of books, in each of the following subjects:—

(*d*) Chemistry, Pure or Applied.
(*e*) Metallurgy.
(*f*) Cotton Spinning.
(*g*) Weaving.
(*h*) Boot and Shoe Manufacture.
(*i*) Building Construction and Carpentry.
(*k*) Naval Architecture.

Each book submitted must be signed by the teacher or professor, as a guarantee of good faith. Stamps for return of books should be sent.

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PERSONAL ITEMS.

AN open competitive examination for twenty-four assistant examiners in the Patent Office will commence on July 19th, 1904. Candidates must be between 20 and 25 years of age on the first day of the examination. The subjects for examination will be :—(1) English Composition (including spelling and handwriting), (2) Geometry (plane and solid), (3) Mechanics and Mechanism, (4) Chemistry, (5) Electricity and Magnetism, (6) General Physics, Hydrostatics, Heat, Light, and Sound, and (7) French or German (translation from the language into English.) No subject is obligatory, but Candidates must obtain such an aggregate number of marks in the examination, as a whole, as may indicate, in the judgment of the Civil Service Commissioners, a competent amount of general proficiency. A fee of £5 will be required from each candidate attending the examination. Application must be made to the *Secretary, Civil Service Commission, Burlington Gardens, London, W.*, on or before June 30th. The salary of an Assistant Examiner in the Patent Office commences at £150 per annum, and rises by yearly increments of £15 to £450 per annum. There is a prospect of promotion to higher posts with salaries ranging from £500 to £800 per annum.

MR. SIDNEY SKINNER has been appointed to the post of Principal of the South-Western Polytechnic, Chelsea, in place of Mr. Herbert Tomlinson, who is retiring. Mr. Skinner has been attached to the teaching staff of the Cavendish Laboratory, Cambridge, since 1888.

THE Hon. C. A. Parsons, F.R.S., will be President of the Engineering Section of the British Association Meeting, which will commence at Cambridge on August 17th.

SHORTLY after the isolation of the element fluorine, M. Henri Moissan determined its density, finding this to be 1·260. This value is considerably less than is required by the atomic weight of fluorine. As a result of recent experiments, M. Moissan announces that after taking minute precautions relating to the purity of the gas, he has obtained the value 1·31 as the mean value for its density. This result is in close agreement with the theoretical value for the density of fluorine, *viz.*, 1·319.

THE GLASGOW UNIVERSITY COURT has appointed Mr. Frederick Soddy to be Lecturer on Physical Chemistry for five years from October 1st next. Mr. Soddy has been associated with Prof. Rutherford in many important discoveries relating to properties of radium and its emanation.

AN exhibition of £50 a year, tenable for two years, is offered by the governing body of Emmanuel College, Cambridge, to an advanced student commencing residence at the College in October, 1904. Applications should be sent to the Master of Emmanuel College not later than October 1st.

CARDIFF UNIVERSITY COLLEGE has accepted an additional donation of £5,500 from the Drapers' Company, toward the building fund of the college. The Drapers' Company had previously contributed £10,000 toward the same building fund.

OLD students of the University College of North Wales have responded to the appeal for funds to provide new and adequate buildings for the college, by subscribing or promising £1,313.

IN April, 1901, there were but six science laboratories in Secondary Schools in Ireland. At the present time there 190 such laboratories, with provision for 3,500 students working simultaneously. Laboratories are now recognised in Ireland as an essential item of equipment.

IN a letter contributed to *Nature* of April 14th, Sir William Ramsay states that the conclusions published by him in *Nature* of April 7th (*see* Progress of Science and Technology, this number of TECHNICS) must be modified. On re-determining the equivalent of the crude oxalate, prepared after the yttrium metals had been separated by treatment with potassium sulphate, it has come out higher than expected—about 240, as the mean of two closely concordant determinations. It appears probable that more than one new element is present ; perhaps these are related to, or identical with, the radio-active elements obtained from thorium residues by Prof. Baskerville.

IN the same number of *Nature*, Mr. J. A. Henry, of the Imperial Institute Scientific and Technical Department, states that Bahr, and later Bunsen and Brauner, have proved that thorium oxalate *is soluble* in excess of ammonium oxalate ; also that this property has been used by Hintz and Weber, and by Glaser, to separate thoria from monazite and similar minerals. Sir William Ramsay's inference, that thoria is not present in large quantities in mineral termed thorianite by Prof. Dunstan, is based on the assumed insolubility of thorium oxalate in ammonium oxalate.

IN a letter to *Engineering* of April 15th, Mr. William B. Bryan describes a simple yet efficient method of making a reservoir drawing pen, which will draw a line of any thickness up to about a quarter of an inch, and several feet in length. An ordinary hinged drawing pen with a long adjusting screw is required ; a piece of sponge, of rather firm texture, is placed therein, and cut with scissors across the end and sides. On charging the sponge with colour or ink, the width of the line drawn can be adjusted by the screw, and there is absolutely no tendency to "blob."

Libraries and Technical Institutions can obtain Reading Cases for "Technics," by applying to the Publisher, George Newnes, Ltd., Southampton Street, Strand, London, W.C.

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RESULTS OF FEBRUARY COMPETITIONS.

GENERAL COMPETITIONS.

No. 1.—**THE BEST SYLLABUS OF PRACTICAL WORK, TO ELUCIDATE THE QUANTITATIVE LAWS OF MAGNETISM AND ELECTRICITY; TOGETHER WITH A DETAILED DESCRIPTION OF THE NECESSARY APPARATUS.**

PRIZE, £10.—S. Irwin Crookes, Rose Villa, Clay Cross, Chesterfield.

No. 2.—**THE BEST CRITICAL ARTICLE DEALING WITH THE RESPECTIVE ADVANTAGES AND DISADVANTAGES OF STEAM ENGINES, PETROL ENGINES, AND SECONDARY CELLS AND MOTORS, FOR USE WITH MOTOR CARS AND CARRIAGES.**

PRIZE, £4.—Jas. Rhodes, Cliffe Cottage, Brow, near Keighley, Yorks.

SPECIAL HONOURABLE MENTION :— F. C. Prentice; W. Headon Owen.

HONOURABLE MENTION :—W. Mackintosh, Junr.

No. 3.—**THE BEST ARTICLE ON POSSIBLE ADVANCES IN THE CHEMICAL INDUSTRIES.**

PRIZE, £3.—Ernest Walls, Cross Bank, Batley, Yorks.

No. 4.—**THE BEST ARTICLE ON "HOW TO ARRANGE ORDINARY WATER PIPES SO AS TO MINIMISE THE RISK OF THEIR BREAKAGE DURING FROSTY WEATHER, AND HOW TO TEMPORARILY MEND THEM WHEN BROKEN."**

PRIZE, £3.—S. Barlow Bennett, Ancoats House, Eaglescliffe, R.S.O.

SPECIAL HONOURABLE MENTION :—Geo. Chasser; James Fergusson Scott.

HONOURABLE MENTION :—John Eden; Charles Henry Kelly; C. B. Wyard; R. Haslam.

No. 5.—**THE BEST SHORT ARTICLE ON "SCIENTIFIC PRINCIPLES AND CALCULATIONS APPLIED TO BREAD-MAKING."**

PRIZE, £2.—E. H. Higgins, 2, Hustler Street, Bradford.

HONOURABLE MENTION :—William Davenport.

No. 6.—**THE BEST DESIGN FOR THE FLOOR OF THE VESTIBULE OF AN ART MUSEUM, TO BE CARRIED OUT IN MOSAIC WORK.**

PRIZE, £2.—John Webb, 52, Edward Street, Burton-on-Trent.

HONOURABLE MENTION :—Martin Shaw Briggs.

No. 7.—**SPECIAL COMPETITIONS.** (See below).

No. 8.—**FOR THE BEST ANSWER TO OPEN QUERY "ALPHA."**

PRIZE, £3.—John Don, 53, King Street, Peterhead.

SPECIAL HONOURABLE MENTION :—Walter Jamieson.

HONOURABLE MENTION :—Donald R. Kennedy.

OPEN QUERY "LOCO."—No answer received.

SPECIAL COMPETITIONS.

I.—CONTINUOUS-CURRENT DYNAMO.

PRIZE, £5.—C. H. Finnis, "Blantyre," Barrowgate Road, Chiswick

SPECIAL HONOURABLE MENTION :—P. E. Banting.

II.—PROF. BARRETT'S PAPER.

PRIZE, £5.—S. E. Allen, 18, Hyde Road, Ladywood, Birmingham.

III.—PHOTOGRAPHY.

PRIZE, £5.—This prize has been equally divided between two competitors :—G. Reucastle Grieve, 4, Garturk Street, Govanhill, Glasgow; Ernest G. Beach, 100, Cowley Road, Brixton, S.W.

SPECIAL HONOURABLE MENTION :—Benj. Pearson, Henry Oscar Klein.

HONOURABLE MENTION :—S. Irwin Crookes; W. Cassels Brown.

IV.—STRUCTURAL DESIGN.

PRIZE, £5.—Percy I. Robinson, District Engineer's Dept., District Offices, Hamilton, N.B.

SPECIAL HONOURABLE MENTION :—Colin S. Campbell; John C. Telford.

HONOURABLE MENTION :—Arthur Morley; G Jerram; Richard Coulson.

We regret that in the April number, the name of the winner of the prize for the Best Single Answer in Special Competitions in the January number, was spelt Sanderson instead of Sandison.

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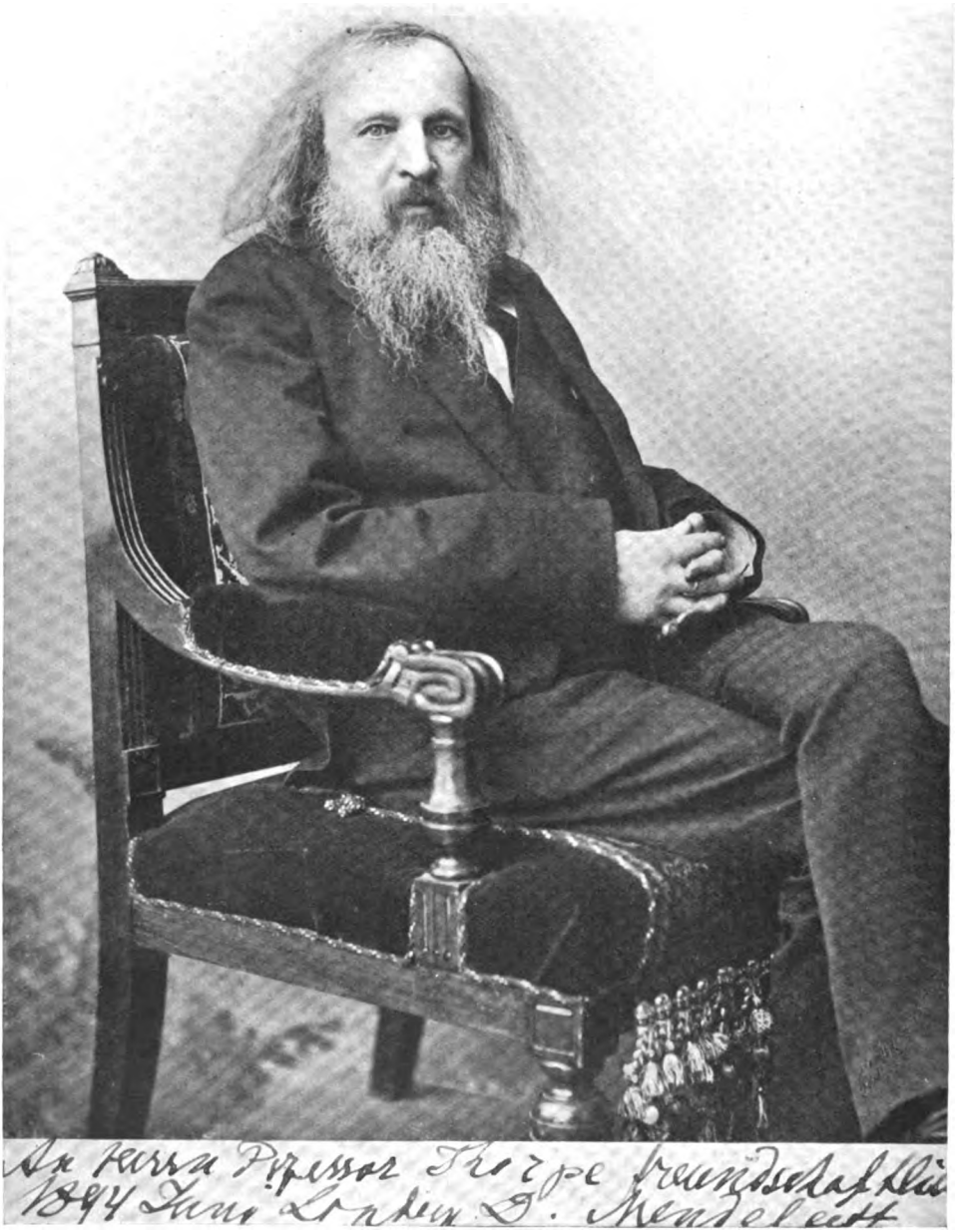

THE CELEBRATED RUSSIAN CHEMIST, PROFESSOR MENDELÉEFF.

(Reproduced from a photograph in the possession of Dr. Thorpe, F.R.S.)

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TECHNICS

A MAGAZINE TO AID TECHNICAL PROGRESS.

VOL. I. JUNE, 1904. NO. 6.

PROGRESS OF SCIENCE AND TECHNOLOGY.

Luminous Phenomena due to Ozone and Radium

FRICHARZ and R. Schenck some time ago communicated to the Berlin Academy of Sciences the observation that blende (zinc-sulphide) becomes luminous in a stream of ozone. In a paper recently read before the same academy, the experimenters record some other cases of luminescence due to ozone. While white phosphorus, as is known, will glow even in air, red phosphorus shows a luminescence only in ozone. This luminescence is of feeble intensity in the case of ordinary red phosphorus, while in the case of phosphorus derived from a phosphorous tri-bromide solution, it is very strong. As regards the disozonising effect of blende and red phosphorus, a stream of ozone which, having been left to itself, was not capable of acting on a steam jet, acts strongly after coming in contact with either of the substances. Among other substances showing a slight luminosity in ozone, may be mentioned vitrious arsenic acid. A drop of turpentine oil shows a strong luminescence. The experimenters even noted that a finger (as well as wool, paper, linen, cotton, etc.) held in a stream of strongly ozonised oxygen escaping into the air, shows a luminescence due most likely to the adherence of ozone. Such bodies smell of ozone even after half or a whole day. As regards the question whether the luminescence is due to the substances themselves being oxidised by ozone, or else to the O-ions being freed by the disaggregation of the ozone, the authors intend making spectroscopic investigations in this direction.

A Novel Process for obtaining Photographs of objects in their Natural Colours

THE principal novelty of a process for obtaining photographs of objects in their natural colours, just brought out in Berlin, is that any ordinary negative may be made to give chromatic prints. Suppose a view of a landscape to be taken with an ordinary plate: the sky, being blue, will throw on the plate the most efficient light, so as to produce on the negative the thickest dark layer. The leaves of the trees, on the other hand, will produce less intense effects, and still less will be the action of the red portions. Now the inventor, Oberleutnant von Slawik, an Austrian, has designed a special kind of printing paper, bearing a number of superposed dye-stuff layers: underneath there is a red layer, in the middle a green, and above a blue layer. The densest portion of the negative, representing the sky, will evidently be the least translucent: the light transmitted by this portion will be able to act only on the upper blue layer, rendering insoluble only the bichromated gelatine of this layer. The thinnest portions of the negative—corresponding, for instance, to a red wall—will, in printing, transmit the greatest amount of light: all three pigment layers being struck by the light will become insoluble, down to the lowest red layer. The green leaves will, as above shown, give rise to a medium density of the plate, and a medium amount of light will penetrate to the paper at the corresponding portions of the plate; this amount of light being just sufficient to render insoluble the two upper blue and green strata, whereas the lowest layer will remain unaltered.

After exposure, the paper is pressed on another sheet of paper, when the coloured layers are transferred from one sheet to the

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other, the print being afterwards "developed" with warm water, in the way usual in pigment printing. After the transference, the lower of the original pigment layers will be uppermost. The warm water will be able to dissolve any jelly layers which have not been rendered insoluble by the action of light. On the portions corresponding to the sky, the green and red layers, which were not acted on by light, will be removed; the blue layer only remaining. In the parts corresponding to the red wall (where the light, as above shown, penetrated to the lowest red layer, which, after transference, is uppermost) no alteration will be produced; while in the portions corresponding to the green leaves, only the red layer will be washed off by the water, thus leaving the green colour visible.

Photo-micrograph by H. de Mosenthal.

FIG. 1. COTTON FIBRE, SHOWING PORES OR STOMATA. (*Magnified 300 diameters.*)

In practice it has been found advisable to use a larger number of coloured layers, instead of those corresponding to the three fundamental colours only, so as to produce all the shades required; up to fourteen pigments are thus used.

The above process has been developed in the laboratory of Dr. Ad. Hesekiel & Co., Berlin. As a matter of course, any old negatives taken at any time may be made to reproduce the true colours of the original.

Cotton Fibres

MORE than one industry depends for its existence on cotton. The importance of the spinning industry, and its dependence on the seed hairs of *Gossypium* need be no more than mentioned to be recognised. Paper made from rags is, of course, indirectly derived from cotton fibres. Gun-cotton (nitro-cellulose) and other explosives, as well as artificial silk and celluloid, are also made from cotton: the cotton fibre provides us with the purest obtainable form of cellulose. Incidentally, it may be remarked that the filaments of electric glow lamps are made from a species of celluloid, carbonised in a crucible packed with charcoal powder. The use of collodion (nitro-cellulose dissolved in alcohol and ether) is less important in connection with photography than it was some years ago; but, on the other hand, incandescent mantles for gas lighting have only reached their present high stage of excellence as a result of the use of this substance. It is, therefore, no subject for surprise that much attention has been paid to determine the structure of the cotton fibre. Bowman's work on *The Structure of the Cotton Fibre in its Relation to Technical Application* (Manchester, 1881) is the source from which most recent writers have obtained their information as to the histology of the cotton fibre. Bowman acknowledged the earlier work of Crum. Hugh Monie, jun., in his book *The Cotton Fibre: its structure, etc.* (London, 1890) deals chiefly with the differences between cottons of different origins. The most important advance effected in recent years is, undoubtedly, that made by H. de Mosenthal, F.I.C., and described in the *Journal of the Society of Chemical Industry*, March 31, 1904. There are few feats in microscopical research, of which any investigator might feel more proud, than that of dividing a cotton fibre longitudinally, and examining the section so obtained. This feat has been accomplished by Mr. de Mosenthal, to whom we are indebted for the photomicrograph of the section to be found in Mr. Beadle's article on "The Fibrous Constituents of Paper (Fig. 4, p. 569). The cotton fibre thus split and examined was just about a

Photo-micrograph by H. de Mosenthal.

FIG. 2. — COTTON FIBRE, SHOWING PORES OR STOMATA. (*Magnified 1,000 diameters.*)

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thousandth of an inch in thickness. It is clearly seen that the walls of the fibre consist of two layers, which have been termed the *outer* and *inner cuticular layers* respectively. Within the inner cuticle lies the *intercuticular substance*, consisting of minute spherical granules of about one twenty-five-thousandth of an inch (0·00004 in.) in diameter. The intercuticular substance constitutes from 85 to 90 per cent. of the total substance of the fibre. Mr. de Mosenthal has succeeded in detecting minute stomata in the cuticle, which had previously escaped observation. Some of these stomata are visible in Figs. 1 and 2: in some cases, as shown in Fig. 3, p. 569, the stomata are arranged in spiral lines. The detection of these stomata explains a phenomenon which previously puzzled scientists. The outer surface of the cuticle is covered with a waxy substance; consequently, when it was observed that the fibres became limp and flaccid in damp weather, the question arose, How does the moisture manage to penetrate into the interior of the fibre? The presence of the stomata explains this point. Mr. de Mosenthal also states that if a single cotton fibre is hung in a vertical position, with its lower end dipping into a liquid, the liquid does not travel up the fibre by capillary action, as might be expected. When a number of fibres, lying side by side, are tested in a similar manner, it is found that the liquid rises in the narrow spaces between the fibres, and reaches the interior of each by way of the pores or stomata. Thus, success in dyeing cotton goods depends on these minute pores —pores so small as to have previously defied detection by the most skilful microscopical investigators. The fact that cotton clothes become damp, even when locked away in a drawer, is attributable to the same cause.

Natural Function of the Stomata

It is probable that the stomata also play an important part in relation to the propagation of the cotton plant. The function of the cotton fibre, like that of other seed hairs, is to enable the seed to which it is attached to be wafted by the wind until a suitable resting-place has been found. Now it is essential that the cotton seed shall fall on dry ground, as moisture rapidly damages it. Thus, were the seeds wafted away in damp weather, they would mostly be killed. The action of the stomata, however, prevents this. In damp weather the cotton fibres absorb moisture, become limp and flaccid, and therefore cling together, thus defying the action of moderate winds. When, however, the weather is dry, the fibres give up their moisture, become tense and elastic, and are easily carried away by the wind; they naturally fall on dry ground, and germinate in due season.

Nitrated Cotton Fibres

Cotton fibres, exposed to the action of concentrated nitric acid, become converted into nitro-cellulose or gun-cotton. This substance is soluble in many liquids, notably acetone, and a mixture of alcohol and ether. The solution may appear quite clear and structureless, leading to the conclusion that the nitro-cellulose has been truly dissolved. Nevertheless, after a time cotton fibres may once more make their appearance. Instances have been recorded, by manufacturers of celluloid, in which the fibres have disappeared for months, and yet have finally reappeared. Sheets of celluloid will sometimes become quite white and opaque owing to this action. Collodion photographic plates sometimes act in a similar manner. Mr. de Mosenthal finds that Schweitzer's reagent (cupric oxide dissolved in ammonia) which apparently dissolves cellulose, forms in reality only an imperfect solution: the granules of the intercuticular substance, and fragments of the cuticle itself, can be afterwards recovered and examined microscopically. Fig. 7, p. 571, represents a fragment of the cuticle recovered in this manner; the stomata and surface corrugation are clearly visible.

Progress in Gas Lighting

The bats-wing, the fish-tail, and the argand flames are now practically defunct: the incandescent mantle, in replacing them, has attained results which, a few years ago, would have been scouted as chimerical. The luminosity of a gas flame, using any of the burners referred to above, depends on the amount of the unsaturated hydrocarbons (such as ethylene and benzene vapour) present in the gas. When these substances are burnt with an insufficient air supply, part of the carbon is temporarily thrown out of combination, and raised to the temperature of the flame. Consequently, the luminosity of the flame is really due to minute particles of incandescent carbon. Saturated hydrocarbons produce little luminosity when burnt; their function, in gas to be used to produce a luminous flame, being merely to increase the temperature of combustion. Thus the amount and nature of the unsaturated hydrocarbons in the gas determine the luminosity of the flame that can be obtained from it. More than

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thirty years ago, and therefore, long before the advent of the mantle, Parliament defined the quality of the gas to be supplied to consumers by the gas companies; as was natural, this definition was based on the luminosity of the resulting gas flame, since at that time gas was scarcely used for any purpose other than that of producing a luminous flame. At the present day the same definition is in force: it specifies that a standard "London" argand burner, producing a 16 candle-power flame, shall consume 5 cubic feet of gas per hour. The gas supplied in London is tested three times a day by representatives of the Board of Trade, to ensure that the gas supplied is of the character specified. In the thirty years which have elapsed since this definition was made law, the needs of gas consumers have undergone a complete change. Gas is now largely used for heating, and for driving internal combustion engines: the presence of the unsaturated hydrocarbon is certainly not necessary, and is sometimes disadvantageous for these purposes. The general use of mantles has now rendered the luminosity of the gas of practically no importance, even for lighting purposes. What is now wanted all round is gas that will produce a *hot* flame, and preferably a non-luminous one. The following table, due to Professor V. B. Lewes, gives the net B.Th.U's.* obtained by the complete combustion of a cubic foot of each ingredient of ordinary coal gas, compared with the candle-power of each ingredient when burnt at the rate of five cubic feet per hour.

Description of Gas.	B.Th.U.'s per c. ft. (net).	Illuminating Value per 5 c. ft. per hour.	B.Th.U.'s per Candle.
Methane . .	919	5·2	984·6
Ethylene . .	1510	70·0	114·6
Benzene vapour	3574	820·0	22·6

It thus becomes evident that the calorific value of a gas is only indirectly dependent on the luminosity of the gas. For example, if a gas owes its luminosity to ethylene mixed with methane, its calorific value will be higher than if the luminosity is due to benzene vapour. With gas made from a certain class of coal, the calorific value will generally increase *pari passu* with the luminosity of the gas; the reason of this being, that the conditions which lead to an enrichment in the light-giving unsaturated hydrocarbons, also lead to an enrichment in methane. But two samples of gas, made from different kinds of coal, so as to give equal luminosities under the legal standard conditions, may have calorific values differing by 10 per cent., or even more.

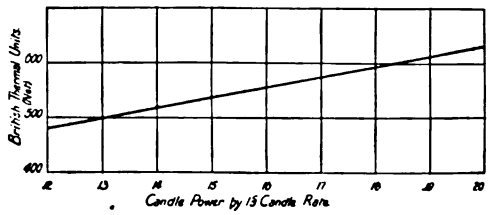

FIG. 3.—GENERAL RELATION BETWEEN THERMAL AND LUMINOUS CAPACITIES OF COAL GAS.

Fig. 3, due to Professor Vivian B. Lewes,* shows the general relation between calorific power and illuminating value of ordinary coal gas. It must be understood that for a given candle-power, the calorific value may be 5 per cent. greater or less than that indicated by the curve, according to the kind of coal used. What the curve shows is this: that although a decrease in the illuminating capacity of the gas is *generally* attended by a decrease in the calorific value, yet the percentage decrease in the latter is much less than that in the former. For example, if 12 candle-power gas were obtainable instead of 16 candle-power gas (implying a diminution of 25 per cent. in the illuminating value), the calorific value would be decreased only from 564 B.Th.U's. to 490 B.Th.U's., or by about 11 per cent. When it is remembered that coal gas, as initially produced, generally has to be enriched with unsaturated hydrocarbon, so as to increase its illuminating value, it will be understood that the price of coal gas can be considerably decreased so soon as Parliament considers the time to be ripe for modifying the standard of gas supplied to suit our present requirements.

The Development and Future of Electric High-Speed Railways

"HIGH-SPEED RAILWAYS" was the subject of a lecture recently delivered in Berlin by Regierungsbaumeister Denninghoff, Manager to the "Studiengesellschaft" by which the well-known Marienfelde-Zossen trials were conducted. It was pointed out that, on October 6th, 1903, when the speed of 125 miles per hour was reached for the first time, just 74 years had elapsed

* A B.Th.U. (British Thermal Unit) will raise the temperature of 1lb. of water through 1° F.

* "Candles and Calories." By Vivian B. Lewes. *Journal of Gas Lighting*, June 16, 1903.

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since, in a competition of four locomotives at Liverpool, Stephenson obtained the prize; resulting in the decision being taken to run the Liverpool-Manchester railway with steam engines instead of with horses. The first railway constructed in Germany (namely, that connecting Nürnberg and Fürth) was run at a maximum speed of 50 km. per hour, while in 1865, a maximum speed of 75 km., and in 1895, figures as high as 100 km. were obtained, this being the maximum speed authorised in Germany. Still higher speeds were used in America.

After giving a short account of the development of electric railways in Germany, and of the Marienfelde-Zossen high-speed trials, Herr Denninghoff points out that measurements of the air resistance, which were made in connection with these trials, have proved that this resistance increases with the square of the speed: being 52 kg. per sq. m. for a speed of 100 km. per hour, and increasing to 208 kg. for a speed as high as 200 km. (125 miles) per hour. The surface of the car, being 10 sq. m., thus opposes a resistance as high as 2,080 kg.; to overcome which 1,500 h.p. will be necessary. The air resistance may be diminished from 10 to 15% by using cars with a pointed or wedge-shaped front. Taking into account the remaining items of the resistance, a speed of 100 km. will correspond with a total resistance as high as 830 kg., to overcome which 310 h.p. will be required; whereas a figure so high as 2,300 kg. is obtained at a speed of 200 km. per hour, necessitating an expenditure of 1,700 h.p. On account of the rapid increase in cost thus entailed, Herr Denninghoff thinks 150 km. per hour will form a practical limit for some time to come. This speed would enable the journey between Berlin and Hamburg to be made in 2 hours, as against the $3\frac{1}{2}$ hours required at present; that between Berlin and Cologne in 4 instead of in 9 hours, and finally, the journey Berlin-Vladivostok in 3 or 4, instead of in 16 days.

As regards the endeavours now being made to improve the speed of steam locomotives, 120 km. per hour seems to represent a practical limit, lest the weight of the locomotive become prohibitory. In fact, a locomotive allowing of this speed will have a weight as high as 140 tons; whereas with electric traction, the whole train run on the high-speed trials weighed only 96 tons.

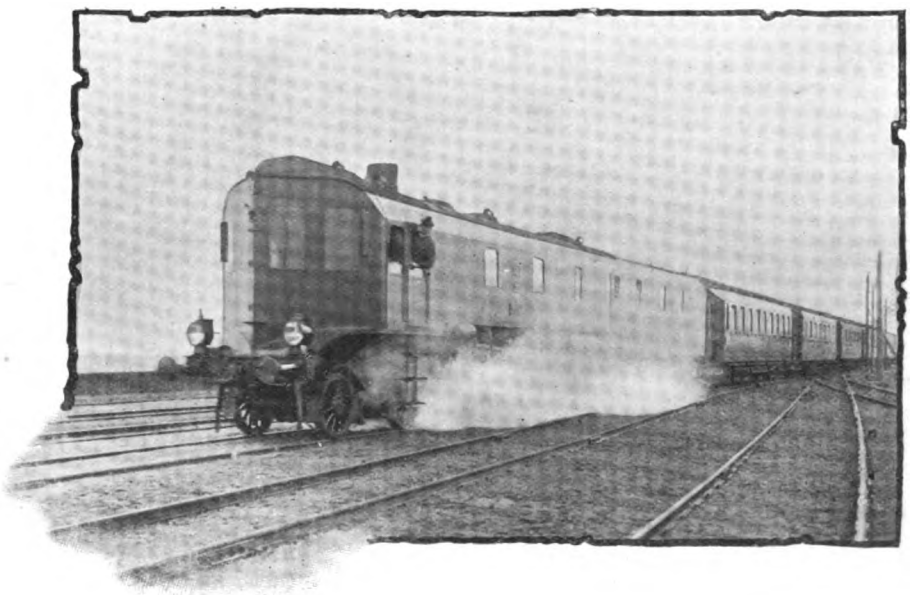

FIG. 4.—HIGH-SPEED LOCOMOTIVE, PRUSSIAN RAILWAYS MINISTRY.

A High-Speed Steam Locomotive

THE external form of the steam locomotive has suffered comparatively little change since the time when the first engine was built. It is stated that Stephenson's locomotive owed its form to its lineal ancestor, the pumping engine. The railway gauge which has survived is practically that of a country

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cart, which owed its dimensions to the width of country lanes. However, everything changes sooner or later, and the high-speed locomotive represented in Fig. 4 bears but small resemblance to its remote ancestor, Puffing Billy. This locomotive has been sent for exhibition, to the St. Louis Exposition, by the Prussian Railway Ministry. Its speed is 130 kilometers (81 miles) per hour.

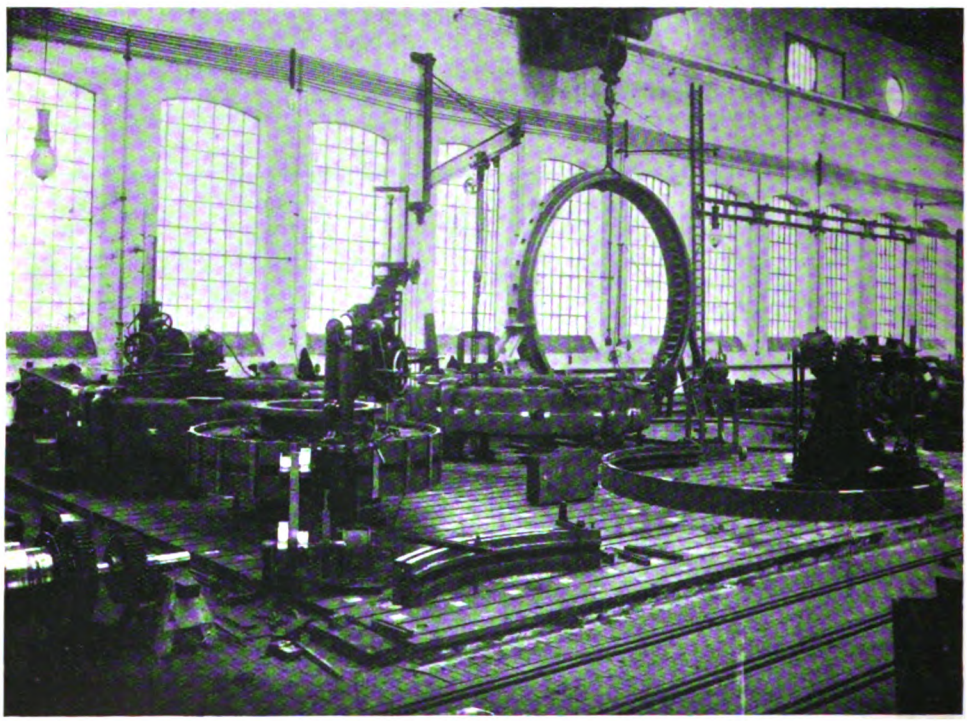

FIG. 5.—NEW WORKSHOP OF THE ELECTRIC CONSTRUCTION COMPANY, WOLVERHAMPTON.

Visit of the Students of the Institution of Electrical Engineers to Works in the Birmingham District

IN addition to the usual weekly visits which the students of the Institution of Electrical Engineers pay to the works and installations in the neighbourhood of London during the winter session, an annual one of a week's duration, which takes place in the Easter vacation, is made to one of the large manufacturing towns in the country. This year Birmingham was chosen as the centre, and a very interesting series of visits was made to power stations and factories in the neighbourhood of this city.

The plants viewed were those of:—

Willans & Robinson, Limited, Rugby:
General Electric Company, Limited, Witton:
Midland Electric Corporation for Power Distribution, Ocker Hill:
Wednesbury Corporation Electric Light Distribution Station:
Electric Construction Company, Wolverhampton:
Wolverhampton Corporation Electric Light Works and Tramways (Surface System):
W. & J. Player, Limited, Birmingham:
Lanchester Engine Company, Birmingham:
Bellis & Morcom, Limited, Birmingham:
Stewarts & Lloyds, Limited, Halesowen:
Birmingham Small Arms Company, Small Heath; and
City Electricity Works, Birmingham.

Electrical Equipment

ONE of the features common to all these works is the practically universal adoption of electric motor driving. Each factory, as a rule, is equipped with its own power station: except in the case of large tools and machines, independent driving is not adopted. The motors drive lengths of shafting, which are usually supported on the columns which hold up the roof, the machines being grouped

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closely underneath, leaving the centres of the bays open; this allows overhead travelling cranes to be used. The centre of the floor is either used for larger machines with independent motors, or for the erection and assembling of machines in the course of construction. The cranes used are all electric, as these can be handled very much more quickly than any other type. A modern type crane, where the strength of the buildings is sufficiently great, is arranged to travel at a rate of 300 feet per minute, and is fitted with as many as five, and sometimes even seven motors; this arrangement is found to add much to the rapidity with which weights can be dealt with, and more than makes up for the cost of the extra motors.

Continuous current is used almost without exception in these works, but there seems to be no unanimity as to the supply pressure: the larger number of factories, perhaps, use 220 volts. The newer works take advantage of the three-wire system for lighting at 230 volts, and use the 460 volts on the outers for their motors, thus greatly reducing the size of the cables used for transmission.

The Electric Construction Company, who have recently erected a very fine new shop for dealing with large alternators of 1,500 k.w. capacity, and even larger sizes, use three-phase motors for the independent driving of the tools. The crane motors in the new shop, however, are driven by continuous current.

Power-house Capacities

As a comparison of the power-house capacities, it may be mentioned that the capacity of the General Electric Company, employing about 1,500 workpeople, is 350 k.w.; while that of Bellis & Morcom, who have about 2,000 men on their books, is 374 k.w. In both cases a portion of this is for a reserve. The General Electric Company's equipment comprises one 150 k.w. Galloway-G.E.C. set, the dynamo being arranged with tappings off the armature to slip rings, so that three-phase alternating current can be obtained for testing purposes; also one 150 k.w. Peache-G.E.C. steam dynamo, and a 50 k.w. Bellis-G.E.C. auxiliary set. The total load at the time of the visit was 480 amperes at 500 volts; so that, for ordinary use, one 150 k.w. generator and the auxiliary set are sufficient, leaving the other 150 k.w. set in reserve. Messrs. Bellis & Morcom's equipment consists of one 308 k.w. Bellis-Silvertown steam dynamo, and one 66 k.w. Bellis-Crompton, the 308 k.w. set being usually run.

In addition to the continuous current generating plant at the Electric Construction Company's works, a three-phase alternator is installed to supply power to their new generator shop, referred to above. By aid of a rotary converter this machine can also supply current to the continuous current motors; if the alternator is shut down, the rotary converter can be used to convert continuous to three-phase alternating current for the motors in the new shop.

The general opinion of works' managers in the Birmingham district is, that the substitution of electrical for steam power has effected a great saving. It must not be forgotten, however, that modern economical plant is used for producing the electricity, in place of the older and more wasteful engines formerly used for direct driving; and, also, modern improvements in the mode of driving the machinery are employed, and the opportunity was taken, when putting in the electric plant, to instal new and better machines and tools. Owing to the severe competition of the present day, it is essential that a factory should be kept at least on level terms with competitors, so that new methods and processes receive more attention than they used to, with the result that the modernising of works is going on much faster than is appreciated by those who are not intimately concerned with such work.

Certain Actions of Radium Rays

RADIUM rays precipitate colloidal silver and other negative colloids, but not positive colloids; they produce and precipitate met-haemoglobin from oxy-haemoglobin; they destroy the activity of the ferments invertin, emulsin and trypsin; they cause red blood corpuscles to more readily give up haemoglobin. V. Henri and A. Mayer; *Comp. rend.*, 138, 521.

Bacterial Origin of Vegetable Gums

DR. R. CREIG SMITH communicated to the Sydney, N.S.W., Section of the Society of Chemical Industry, in December, 1903, the results of an exhaustive and interesting inquiry on this subject. He showed that bacteria inhabiting the tissues of gum-bearing trees can form arabin, metarabin, pararabin, and other gums, and concluded that the arabin gums are bacterial in origin. Further, he indicated how the yield of gum-bearing trees might be increased by artificial infection.

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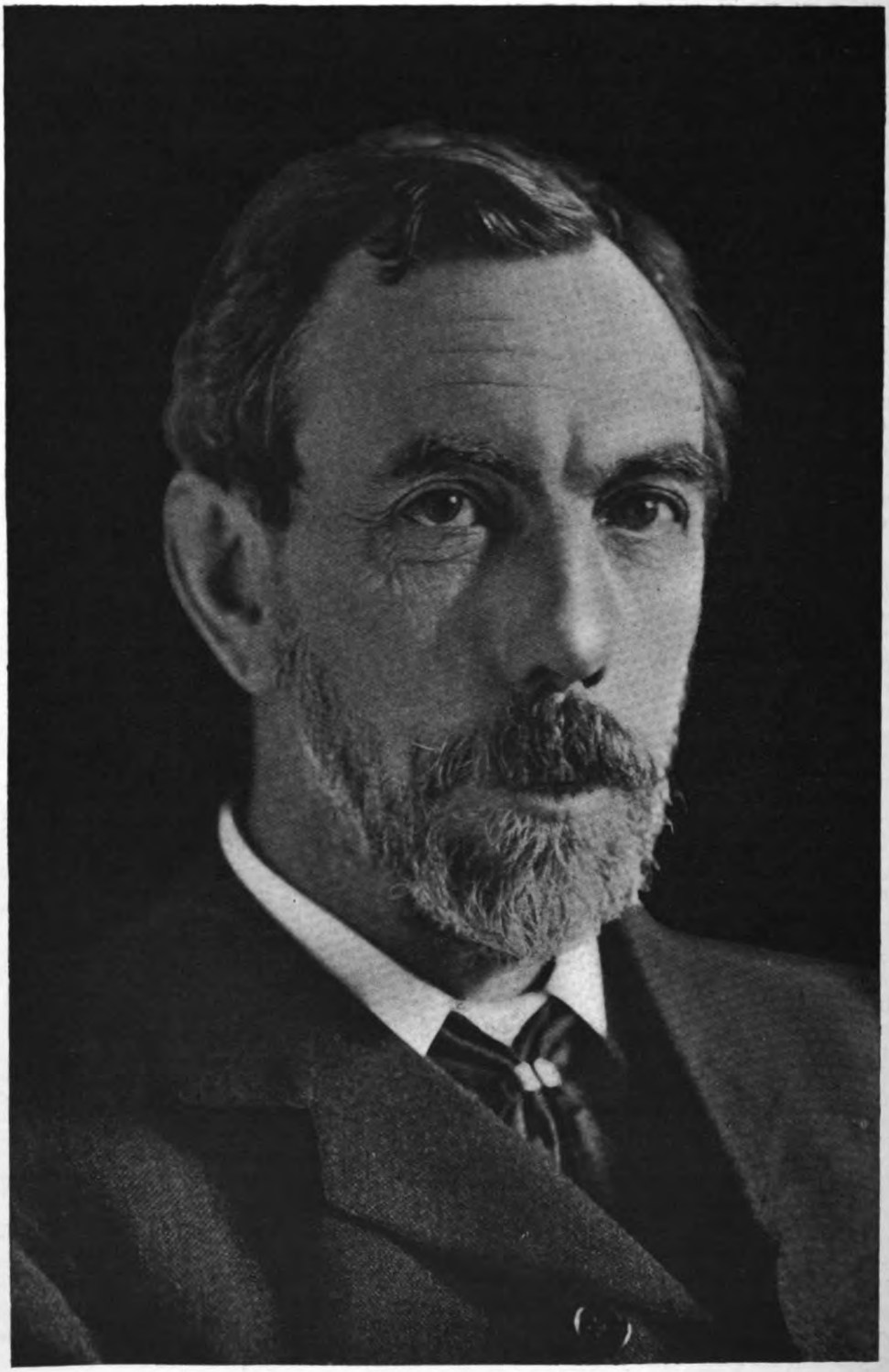

SIR WILLIAM RAMSAY, K.C.B., F.R.S.

(Photo. by George Newnes, Ltd.)

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ON THE PERIODIC ARRANGEMENT OF THE ELEMENTS.

By Sir WILLIAM RAMSAY, K.C.B., F.R.S.

AT the end of the eighteenth century, after the investigations of Black, Scheele, Priestley, Cavendish, and Lavoisier began to crystallise the previous arbitrary collections of chemical facts into more or less of a system, it became evident that the distinguishing feature of a "compound," as contrasted with a "mixture," was the invariability of its composition. Early in the nineteenth century, Dalton formulated his celebrated hypothesis, by means of which a concrete view was gained regarding the cause of this constancy and invariability of composition. Everyone knows that this "explanation" consisted in the supposition that the combination of two substances, one with another, in definite proportions, involves the union either of one atom of the one with one atom of the other, or of certain small but simple numbers of atoms of the two substances. The atom was regarded, not necessarily as indivisible, but as not having been divided into any smaller particles. The advance made by Dalton consisted chiefly in ascribing to each atom a definite weight; but as he had no data for determining the absolute weight of any one atom, he was obliged to content himself with relative weights, and chose the smallest known to him, that of hydrogen, as an arbitrary unit. This choice has proved to be a just one, for as yet, no element has been discovered possessing a lower atomic weight than hydrogen, although it is by no means impossible that such an element may exist.

After the convenience of Dalton's hypothesis had been acknowledged, the labour of chemists was for many years devoted to the determination of the relative values of the "atomic weights" of the elements; or expressed in a manner independent of hypothesis, of their combining proportions. The name of the Swedish chemist, Berzelius, is prominent in this connection. By the analysis of an almost incredibly large number of compounds, he established on a firm basis the constancy of composition of compounds, and the law of multiple proportions. Towards the '40's, therefore, a set of numbers had been collected, which invited an attempt to place them in order, with the view of seeing whether some still more profound law could not be discovered connecting the combining numbers attached to them. Döbereiner, as early as 1817, and again in 1829, pointed out that certain elements had atomic weights which were nearly the mean of those of others which were closely related to them; thus, the mean of the atomic weights of calcium and barium gives a close approximation to the atomic weight of strontium; that of sodium lies near the mean of those of lithium and potassium; and sulphur and tellurium similarly indicate selenium as a middle element. In 1843, Gmelin, who published a "Handbook of Chemistry" which is still a classic, attempted a classification based, not upon numerical relations, but on similarity of properties. For instance, we find the groups—F, Cl, Br, I; S, Se, Te; P, As, Sb; C, B, Si; Li, Na, K; Mg, Ca, Sr, Ba; and so on. In 1851, Dumas gave a lecture before the British Association, in which he showed that not merely is the atomic weight of bromine the mean of those of chlorine and iodine, but that its physical properties, such as its colour, its density in the gaseous and in the liquid state, etc., are also half-way between those of the allied elements. In 1852, Faraday criticised Dumas' attempts as "speculations which have scarcely yet assumed the consistence of a theory, and which are only at the present time to be ranked among the poetic day-dreams of a philosopher," and he proceeded:—"We seem here to have the dawning of a new light indicative of the mutual convertibility of certain groups of elements, although under conditions which are as yet hidden from our scrutiny."

Passing over attempts by Gladstone, Cooke, Odling, and Strecker, we come to the years 1863 and 1864, when John Newlands, in a series of letters to the "Chemical News," announced what he termed the "Law of Octaves." His actual words were:—"If the elements are arranged in the order of their equivalents, with a few slight transpositions, it will be observed that elements belonging to the same group usually appear on the same horizontal line. It will also be seen that the numbers of analogous elements generally differ, either by 7 or by some multiple of 7; in other words, members of the same group stand to each other in the same relation

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I.	II.	III.	IV.	V.	VI.	VII.	VIII.		
Li 7·03	Be 9·1	B 11·0	C 12·0	N. 14·04	O 16·00	F 19		*He 4*	
Na 23·05	Mg 24·36	Al 27·1	Si 28·4	P 31·0	S 32·06	Cl 35·45		*Ne 20*	
K 39·14	Ca 40·0	Sc 44	Ti 48·1	V 51·2	Cr 52·1	Mn 55·0	Fe 56·0	Co 59·0	Ni 58·7
Cu 63·6	Zn 65·4	Ga 70	Ge 74	As 75	Se 79·1	Br 79·96		*Kr 81·5*	
Rb 85·4	Sr 87·6	Y 89	Zr 90·6	Nb 94	Mo 96·0	? 99	Ru 101·7	Rh 103·0	Pd 106
Ag 107·95	Cd 112	In 114	Sn 119·0	Sb 120	Te 127·6	I 126·85		*X 128*	
Cs 133·0	Ba 137·16	La 138	Ce 140	Prd 141	Nd 143·5	? 152			
? 165	? 170	Yb 173	? 176	Ta 183	W 184	? 185	Os 191	Ir 193	Pt 195·2
Au 197·2	Hg 200·3	Tl 204·1	Pb 206·9	Bi 208·5	? 210	? 211		?	
? 222	Ra 225	? 230	Th 232	? 234	U 240	? 242			

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as the extremities of one or more octaves in music. Thus, in the nitrogen group, between nitrogen and phosphorus there are 7 elements; between phosphorus and arsenic, 14; between arsenic and antimony, 14; and lastly, between antimony and bismuth, 14 also. This peculiar relationship I propose provisionally to term the 'Law of Octaves.'"

In 1869 and 1870, Lothar Meyer and Dmitri Mendeléeff, independently of Newlands, and also of each other, published papers in which they maintained that the properties of the elements are periodic functions of their atomic weights. This discovery goes by the name of the "Periodic Law," or better, the "Periodic System." The arrangement of Meyer (p. 532), which differs but little from that of Mendeléeff, is the one generally adopted.

If this diagram is rolled round a cylinder, it will form a continuous spiral, beginning with lithium and ending with uranium; but there are certain gaps unfilled, denoted by the sign ?, which, it is believed, represent the places of still undiscovered elements. Indeed, Meyer's original diagram contained a larger number of these; and Mendeléeff, averaging the properties of the elements surrounding such gaps, prophesied the discovery of scandium, gallium, and germanium, made at a much later date by Cleve, by Lecoq de Boisbaudran, and by Winckler.

There are many other ways of representing these relations; but, except perhaps in convenience (and questionably even in that), they present no particular advantage, and convey no new knowledge. Only one point must be emphasised. The elements, as arranged above, divide themselves into two "periods"—long periods, and short periods. Thus, the seventh member after lithium, sodium, is in its character very like lithium; and again, potassium, the seventh after sodium, presents strong analogies with the two elements named; but it is then necessary to pass over fourteen elements before rubidium is reached, which again closely resembles lithium, sodium, and potassium; and cæsium, the fourteenth element after rubidium, forms the first term of another long period. Copper, silver, and gold are also separated by long periods; and so with the elements in the other columns. To distinguish these in the table, the symbols of the elements in the middle of the long periods are printed towards the left, and those at the beginning towards the right, of the figures denoting the atomic weights.

One other point requires mention. Several instances occur, in which the elements appear to occupy a reversed position. Thus, nickel, with the atomic weight 58·7, follows cobalt, to which a higher atomic weight is ascribed; tellurium precedes, instead of following iodine; and it will be seen that argon precedes potassium. The differences between the various consecutive atomic weights are irregular, and vary between fairly wide limits; and it is quite probable that these differences may occasionally be negative.

In 1894, a new constituent of the atmosphere, which was named "argon," was discovered by Lord Rayleigh and Ramsay; this was followed, in 1895, by the discovery by Ramsay of helium in certain minerals. This gas gives a spectrum in which a brilliant yellow line is conspicuous. So long ago as 1868 this line had been observed in the solar spectrum by Jansen; it was attributed to the presence of a new element in the sun, by Frankland and Lockyer, and they named the then unknown element "helium." These discoveries were followed by that of three other gaseous elements in atmospheric air, by Ramsay and Travers in 1898; thus five elements were added to the list. All these elements are distinguished by their inertness, for none of them forms compounds with other elements.

The Roman figures at the head of the columns of the periodic table have a certain significance. They show the maximum number of atoms of hydrogen which the elements in each column can combine with or replace, or, as it is termed, their "valency." Thus, an atom of lithium combines with one atom of hydrogen; it can also replace one atom, as when it forms lithium hydroxide, LiOH, in which it has replaced one atom of hydrogen in water, H_2O. So also, magnesium can replace two atoms of hydrogen, for it forms the hydroxide $Mg(OH)_2$. Boron combines with three atoms of hydrogen; carbon with four; phosphorus, although it can combine with only three atoms of hydrogen, can replace five; for it forms a chloride PCl_5, in which it has replaced the five atoms of hydrogen in five molecules of hydrogen chloride, 5HCl. Sulphur forms a hexafluoride, and iodine a heptafluoride, in which they replace six and seven atoms of hydrogen respectively, in 6HF, and in 7HF. Only one of the elements of the eighth group appears to be able to replace 8 atoms of hydrogen, namely, osmium; it forms a tetroxide, OsO_4, thus replacing the eight atoms of hydrogen in four molecules of water, $4H_2O$. But the new gaseous elements of the atmosphere form no compounds, and have no valency, as

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the power of replacing or combining with hydrogen is termed. They thus form a column by themselves; and it was interesting to ascertain whether their atomic weights would form a series like those in the other columns. In this case, the atomic weight could not be determined by the usual process of determining the ratio in which the elements combine with hydrogen; hence a different method was adopted, depending on the known fact that equal numbers of molecules of gases occupy equal volumes under the same conditions of temperature and pressure; and making use of an argument relating to the number of atoms in such molecules. The atomic weights were:—

Helium	Neon	Argon	Krypton	Xenon
4	20	39·9	81·5	128

These numbers, as will be seen on reference to the table, fit in the eighth column; the symbols and atomic weights of these gases are printed in italics. They form the initial members of the first, second, and third short series, and of the first and second long series.

Some doubt exists as to the place to be assigned to hydrogen, the element with lowest atomic weight. Both Mendeléeff and Meyer shirked placing it. It may be that it should be placed at the head of the fluorine column; but there are equally good, or perhaps better reasons for believing that it is the first member of the lithium column.

Many attempts have been made to devise some mathematical relation between these atomic weights. So long as there was reason to doubt the accuracy of the experiments by means of which the atomic weights have been determined, some such relation as the following had considerable probability in its favour:—Taking the differences between the atomic weights of the elements in the first column, lithium, sodium, potassium, rubidium, and cæsium, they are

$$Na - Li = 23 - 7 = 16;$$

$$K - Na = 39 - 23 = 16;$$

$$Rb - K = 85 - 39 = 46 = (3 \times 16) \text{ nearly};$$

$$Cs - Rb = 133 - 85 = 48 = (3 \times 16).$$

The differences are 16, 16, 3 × 16, and 3 × 16. Now there are compounds of carbon and hydrogen, which possess the formulæ, CH_4, C_2H_6, C_3H_8, C_4H_{10}, C_5H_{12}, C_6H_{14}, etc.: and as the atomic weight of carbon is 12, and that of hydrogen 1, the sum of the atomic weights, or, as they are called, the molecular weights, are respectively 16, 30, 44, 58, 72, 86, etc., with a common difference of 14. We see, therefore, that a set of compounds may so differ in molecular weight as to present a regular series, with a common difference. Nothing was more likely, then, than that sodium should be regarded as a compound of one atom of lithium with one atom of an unknown element of atomic weight 16, or with two atoms of an unknown element of atomic weight 8; while potassium might be looked upon as a compound of an atom of lithium, with four atoms of the element of atomic weight 8; and so on. But, unfortunately for this simple theory, the differences between the atomic weights of the elements are not exactly equal. Instead of 16, the real difference betweeen the atomic weights of lithium and sodium is 16·02; between potassium and sodium, 16·09; and so on. In other groups the divergences are still more striking.

The cause of this irregularity has, therefore, to be sought. In seeking for a clue, the first question is: Are the atomic weights invariable? A further question is: Is weight invariable? Does a body always possess the same weight under all conditions? For example, would the weight of a body remain the same, if it were to be weighed at different temperatures? Or, if electrically charged, would its weight remain unaltered?

It is a very difficult problem to weigh an object at a high temperature. If the balance, as is usual, contains air, convection currents are produced by the ascent of air heated by the warm body, and the body apparently weighs too little. If the whole balance were uniformly heated, the weights would be at the same temperature as the substance weighed; and it is to be presumed that both they and the substance would alter in weight equally, and still remain in counterpoise. And if the balance case be pumped empty of air, as was done by Crookes in determining the atomic weight of thallium, other phenomena intervene, which, however interesting in themselves (they led Crookes to the invention of the radiometer), are very disconcerting; for attractions and repulsions, which completely disturb equilibrium, are produced by the slightest variations of temperature. However, some curious calculations have been made by Hicks in dealing with Baily's experiments on the attraction of leaden balls by masses of lead—experiments which afford data for calculating the density of the earth.

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At a high temperature the attraction appeared to be less than at a low one; and as the attraction of the earth is the cause of weight, supposing these experiments to be correct, and the deductions legitimate, it would follow that weight is altered by temperature. The subject is well worthy of further experiment.

Again, interesting experiments have been made by Landolt, as regards constancy of weight. Having sealed up in an inverted U-tube, two substances capable of acting on each other, such as silver nitrate and sodium chloride, each substance in solution occupying one limb of the tube, he weighed the tube with the utmost accuracy; the possible error might be one part in a million. On inverting the tube, the two solutions mixed, and the reaction took place. It was again weighed. For long, Landolt supposed that he had detected small changes in weight, sometimes negative, sometimes positive; but he was able to trace these changes to the porous nature of glass. On employing tubes made of fused quartz, no change of weight could be detected after the reaction was over. Apparently, therefore, no change of weight takes place as the result of a chemical reaction, provided nothing leaves or enters the vessel in which the reaction goes on.

A very ingenious experiment of Joly's deserves mention. It was designed to try whether any change of mass occurs on mixing two reacting bodies, and the disposition of the apparatus was somewhat like that devised by Landolt. But instead of utilising the attraction of the earth in order to estimate whether the mass had changed or not, the inertia of the substances and of their mixture was determined. The vessel containing the substances to be mixed was suspended to the arm of a torsion-balance, the arm of which was at right angles to the direction of motion of the earth, which is known to be at the rate of about 30 miles a second through space. If matter had been created during the chemical change, then the created matter would not partake of the earth's velocity, and a retardation, made manifest by the rotation of the arms of the torsion-balance in one direction, would have been observed; and if, on the other hand, matter had been destroyed, an acceleration would have shown itself. The experiments were entirely negative; hence it may be concluded, confirmatory of the experiments of Landolt, that no change in mass is produced by a chemical reaction. A variation in weight or in inertia has not been observed.

There is one curious discrepancy which still remains unexplained. The density of nitrogen gas has been very accurately determined by two very competent observers—Lord Rayleigh and Leduc. They both agree in their results to one part in 10,000. Now it is known, for reasons into which we cannot enter here, that the molecules of both nitrogen and oxygen consist each of two atoms; and as it is also certain that equal volumes of gases contain nearly equal numbers of molecules, when measured under similar conditions of temperature and pressure, the relative weights of these gases correspond to the relative weights of the atoms. The word "nearly" has been used; for a slight correction must be introduced in order to secure exact correspondence. Hence the atomic weight of nitrogen, referred to that of oxygen taken as 16, as is now customary, must be 14·002, since that is the density of nitrogen referred to oxygen as 16, after the necessary correction has been made. But this number does not correspond with the atomic weight of nitrogen obtained by the celebrated chemist Stas, as the result of the analysis of such compounds as potassium nitrate, when he determined the ratio between the quantities of nitrogen and oxygen in the molecule $K N O_3$. Both he and, quite recently, one of the most skilful of analysts, to whom we owe in recent years many exact determinations of atomic weights, Theodore Richards, agree in ascribing the number 14·04 to nitrogen as its atomic weight. The difference does not appear very great; but yet it amounts to one part in 370: and the error of experiment is not likely to be greater than one part in 10,000. This discrepancy is one of the most curious of chemical facts, and it would well repay further investigation. It may be added that the determination by Gray of the density of nitric oxide, a compound containing one atom of nitrogen in combination with one atom of oxygen, entirely corroborates the results of Lord Rayleigh and Leduc. Experiments are now in progress to combine a weighed quantity of nitric oxide with oxygen, so as to cause it to take up one other atom of oxygen, and to find the increase in weight; and also to remove from it the atom of oxygen, and to find the weight of the oxygen removed; we may, therefore, hope for some explanation of the above discrepancy at no distant date.

The writer of this article was so much impressed by the consideration of this discrepancy, that some years ago, in conjunction with Miss Aston, an attempt was made to find whether the fact of a compound having

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been formed with absorption, instead of, as is commoner, with evolution of heat, had any influence on the proportions of the elements which it contained. For this purpose the salts of a curious acid derivative of nitrogen named hydrazoic acid, HN_3, were analysed; but there is reason to distrust the results, for it is possible that decomposition occurred during the preparation to some small extent, and so may not have led to trustworthy conclusions. But such as they were, they were in favour of the supposition that the atomic weight of nitrogen in such compounds is less than in those formed with evolution of heat, like the nitre analysed by Stas and by Richards.

An entirely new light has been thrown on the numerical relations of the atoms by the remarkable discovery of radium by the Curies, and by the discovery by Rutherford and Soddy, that what are termed the "rays" from its salts, as well as from those of thorium, are produced by gases resembling in their inertness the gases of the argon group. These gases, moreover, have the extraordinary property that they are transient, although they change in very different intervals of time. Whereas the gas from thorium is half gone in about a minute (that is, has changed to the extent of one-half into some other substance or substances), that from radium requires about four days before it has undergone half the change of which it is capable. A third gas has been obtained from a radio-active element to which the name "actinium" has been given by its discoverer, Debierne; this gas has an extraordinarily short life, for the total duration of its existence is only a few seconds. The spectrum of the gas from radium has been mapped by Ramsay and Collie; the amount of gas produced from a known weight of radium bromide has been measured by Ramsay and Soddy; and they, too, proved that one of its products of decomposition is the lightest gas of the argon group, helium. At first, the spectrum of the emanation from radium shows none of the characteristic lines of helium; but in the course of a few days the helium spectrum appears in full brilliancy. Here, evidently, is a case of the transformation of one element into another; no doubt there are other products than helium, but what they are remains for the present unknown. If they were elements like iron, for example, there are at present no known means delicate enough to detect the extremely minute amount which would be produced. These gases from radium, thorium, and actinium are self-luminous, and shine brilliantly in the dark; and they also possess the power of altering air and other gases with which they are mixed, so that they acquire the property of discharging an electrified body; the air is said to be "ionised." But a still more remarkable property is their giving off heat during their change into other elements, the amount of heat being enormous when their extremely small quantity is considered. Thus, the radium emanation (the name applied to the gas which is continuously evolved from salts of radium during their existence of about 1,100 years; for, at the end of that time, the change is complete, and no more radium is left as such), during the 28 days of its decomposition, gives off no less than three million times the heat which would be evolved during the explosion of an equal volume of a mixture of oxygen and hydrogen in the proportion requisite to form water. Now, if radium is disappearing, it must be continually in process of formation, else there would be none on the surface of the earth; it would all have disappeared and have been changed into other bodies in 1,100 years. As radium is always associated with uranium, it appears not unreasonable to suppose that uranium, too, which is a radio-active element, is slowly changing into radium; and there appears to be definite ground for the surmise that polonium, the first of the radio-active elements, also discovered by Madame Curie, which has a life of little more than one year, is a product of the decomposition of radium, with which it is always associated. It may be mentioned, too, that all minerals containing uranium contain more or less helium.

It will be noticed, on referring to the periodic table, that all the radio-active elements, that is, all those which are undergoing change of the nature described, have very high atomic weights. That of uranium is 240; that of thorium, 232; and that of radium, 225. Now, it is a commonplace of the organic chemist that it is not possible to build up compounds of carbon and hydrogen of unlimited complexity; indeed, it is doubtful if any compound has been prepared containing more than 54 atoms of carbon. Attempts to prepare them lead to failure, owing to their decomposing at the ordinary temperature into compounds containing a smaller number of atoms. And it is probable that more complex hydrocarbons, as such compounds are termed, would, if they could exist, decompose with evolution of heat. Such a decomposition appears to present analogy with the change which an element

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like radium is undergoing. It is in process of change into other elements of lower atomic weight; and in changing, it evolves heat, in amount enormously greater than that produced by any change of a compound into a mixture of simpler compounds. But the matter is complicated by another phenomenon—that of discharging, with almost inconceivable velocity, particles which appear, according to J. J. Thomson, to be identical with negative electricity. These "corpuscles," as they have been termed, imbed themselves in the vessel in which the radio-active body is confined; and, owing to their extreme minuteness, they may even pass through the walls of the containing vessel. Indeed, the opposition to their passage has been shown to depend merely on the density of the matter of which the confining walls are composed; gold, which is denser than lead, stops their passage better than lead; for a similar reason lead is better than iron, iron better than glass, and so on. Thomson has calculated that the mass of one such particle is approximately one-thousandth of that of an atom of hydrogen.

This new chemistry is just at its commencement. It dates from 1896, when Becquerel showed that compounds of uranium evolved some sort of radiation, which would impress a photographic plate. It is still too early to formulate any definite statement relating to its connection with the irregularity in the numerical sequence of the atomic weights; yet it may be permissible to speculate, aided by the recent discoveries. When two elements combine, heat is generally evolved; now heat is only one form of energy, and the combination of elements may be so carried out as to be accompanied by other kinds of energy—for instance, by the production of an electric current. Conversely, when a compound is resolved into its elements, it is generally necessary to impart energy to it; and the element may, therefore, be said to "contain" more energy than its compounds. Now, as Ostwald has pointed out in his "Faraday" lecture, the progress of discovery has kept pace with the amount of energy with which it was possible at the time to load a compound; and he cited the discovery of the metals of the alkalies, sodium, and potassium, by Davy. It was because Davy had at his disposal the powerful battery of the Royal Institution, that he was able to convey enough energy into caustic potash to isolate from it potassium, hydrogen, and oxygen. If we assume that radium, as may be possible, is produced by a spontaneous change in uranium; and if we also assume that radium contains more energy than uranium; then, as such a spontaneous change must be accompanied, on the whole, by a loss of energy, there must be formed other bodies from the uranium which contain less energy than it does. Such a substance may be iron, which is generally found in company with uranium. If we could concentrate energy into iron, it might be possible to convert it into uranium.

But there is another side to this question. The nature of the energy required appears to be electric in character. Now, it is almost certain that negative electricity is a particular form of matter; and positive electricity is matter deprived of negative electricity—that is, minus this electric matter. The addition of matter in any form would, according to all experience, increase mass; it would also increase weight. It is, therefore, conceivable that an element may consist of a compound of two or more elements of lower atomic weight, plus a certain quantity of negative electricity. This might account for the approximate numerical relations which subsist between the atomic weights of the nearly related elements; and also for the fact that the relation is not an exact one, but only approximate; for the difference between the actual atomic weight, and that which would follow if one element were a compound of other elements of lower atomic weights, would be caused by the addition of a certain number of electric atoms to the molecule.

It must be confessed, however, that the basis for speculations like these is a slender one; the sole ground is the undoubted fact that radium produces an emanation, which spontaneously changes into helium; and also that, in doing so, the emanation parts with a large number of corpuscles carrying negative charges. Nevertheless, enough is known to prove that there is a wide field for experiment, and that the harvest will be a rich one; further, the reapers' task will be one of extraordinary interest.

William Ramsay.

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INCANDESCENT GAS LIGHTING.

By HAROLD M. ROYLE.

THE LUCAS LAMP.

THE incandescent mantle has quite revolutionised the art of gas lighting: in fact, if it had not been for the invention of Dr. Carl Auer, Ritter von Welsbach, the gas industry would have found it practically impossible to hold its own against the electric light; whereas now it is not only holding its own, but more than its own, many places having reverted to incandescent gas lighting after an extensive experience with electricity.

The year 1886 marked the first appearance of the Welsbach incandescent mantle, which soon attained a well-earned success. Dr. Welsbach conceived the idea of making a mantle of refractory oxides, using methods which had previously been tried by others without success. His process consisted in soaking an open fabric of cotton in a solution of the nitrates of the metals of which the oxides are required, drying, and burning off the organic matter; the nitrates thereby becoming converted into their respective oxides, while retaining the shape of the original fabric. Various modifications have been introduced in the manufacture of the fabric, and in the composition of the dipping material, until at the present time the light obtained from the incandescent mantle is far and away superior to that produced by any other method from coal gas.

MANUFACTURE OF MANTLES.

The most successful form of mantle is made by taking a cylinder of cotton net about 8 inches long (or as long as the mantle is required to be after subjecting it to the process of dipping, etc., allowing, of course, for the shrinkage that will take place), one end of which is sewn together with an asbestos thread: a loop of the same material, or of thin platinum wire, is fixed across the constricted portion to provide a support by which the mantle may be held by the carrying rod, which is either external to the mantle (Fig. 1) or (as is often the case) fixed centrally in the burner head (Fig. 2).

After being sewn, the cotton net is soaked in a solution of the nitrates of the requisite metals until the microscopic fibres of the cotton are entirely filled with liquid.

A longer soaking is not advantageous, since the acid nature of the liquid employed tends to weaken the fabric, and render it more delicate to handle. The cotton fabric is then squeezed in a machine, to free it from the excess of liquid attached to the exterior of the threads; after which it is stretched over a conical mould, of the shape the mantle is required to assume, and dried. It is then ready for "burning off," in which process the organic matter is removed and the nitrates converted into oxides. The flame of an atmospheric burner is applied to the constricted portion at the top of the mantle, whereupon the cotton gradually burns downwards. The shape of the mantle to a great extent depends upon the regularity with which the combustion takes place.

A certain amount of carbon is left behind after the flame has died out, and this is burnt off by the application of a Bunsen flame. The action which takes place during this burning off is as follows:—

FIG. 1. THE "KEITH" BURNER.

The tubes of the cotton fibre are initially filled with the crystallised nitrates of the metals used; and as the cellulose burns, the nitrates are decomposed, giving up oxygen and forming fusible nitrates, which in their semi-liquid condition are rendered coherent by the rapid shrinkage which takes place. As the action continues, the nitrates become oxides, losing their fusibility; so that by the time the organic matter has disappeared, coherent threads of oxide are left in the place of the nitrate-laden threads of cotton.

In the early days of mantles, they were sent out without being

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burnt off, the consumer having to perform this operation: there was then no known process which would render them suitable for package or carriage after they were burnt off.

As the success of the mantle depends upon it fitting the flame, and as the burning off requires considerable skill, this was a great difficulty.

Moreover, the acid nature of the nitrates present in the fibres rapidly rotted them, unless they had been subjected to the action of ammonia gas, which neutralised any excess of acid; but it was found that the treatment with ammonia rendered them, after burning off, even more fragile than before, as the fusible nitrates were converted into hydrates, which could not be formed into a coherent mass during the burning off. It was discovered, however, that the burnt-off mantle can be temporarily strengthened by being dipped in collodion, (a solution of soluble gun-cotton in ether and alcohol), together with a little castor oil or similar material to prevent excessive shrinkage during drying; when the mantle is removed from the solution, a thin film of solid collodion remains on it. These mantles can now be easily packed and sent abroad without fear of breakage. When the mantle is required for use, it is only necessary to place it on the burner in its proper position and apply a light at the bottom, when the collodion burns off, leaving the mantle ready for use.

FIG. 2.—WELSBACH "C" BURNER.

The oxides first used in England for Welsbach mantles consisted of mixtures of zirconia, lanthania and yttria; or zirconia and lanthania; but these gave a very fragile mantle and a poor light.

In 1886 the second Welsbach patent was taken out, which covered the use of thoria, either alone or mixed with zirconia, magnesia, yttria, erbia, lanthania, alumina, etc. The idea held at the time was that thoria increased the luminous emissivity of the mantle; but, in point of fact, thoria emits no light at all, although later experience shows that it possesses important properties for mantle making, its refractory nature giving the mantle a stability unattainable by the addition of any other known substance.

At present, nearly all mantles consist of 99 per cent. of thoria with 1 per cent. of ceria, this latter oxide having light-giving qualities far in advance of any other.

Many experiments have been made in order to ascertain the effect of different percentage of ceria when added to thoria, and the results obtained show that, starting with a pure thoria mantle giving practically no light, the candle power rapidly increases as traces of ceria are added to it, until a point is reached at which an increase in the amount of ceria *decreases* the amount of light emitted, the colour of the light also acquiring a yellow tint, which gradually deepens to a reddish character with excess of ceria.* These results show such a narrow limit for production of the highest light-emissivity, that a very careful proportioning of the liquid used for soaking the mantle is necessary. The light from a Welsbach mantle generally increases for a certain period, and then steadily falls off. The initial increase is probably due to the mantle shaping itself to the flame, thereby attaining a higher temperature. The subsequent diminution in luminosity is chiefly due to dusty particles containing silica, which are drawn on to the surface of the mantle by the chimney draught, and, fusing on the outside of the fine filaments of the mantle, form silicates, which have a much lower luminous emissivity than the original oxides.

Many theories have been advanced to explain the marvellous capacity possessed by minute traces of ceria in exciting the light emissivity of the mantle.

In the explanation due to Dr. Bunté, the action is ascribed to a catalysis of the same nature as causes a piece of clean platinum foil to become red-hot when a mixture of coal gas and air is allowed to impinge upon it, the action being due to the capacity which the platinum has of condensing within its pores both hydrogen and oxygen, and rendering them so chemically active that they unite upon the surface of the metal and emit sufficient heat

* [For a discussion of the part played by ceria in increasing the luminosity of a mantle, see Mr. Jas. Swinburne's article on Incandescent Electric Lamps, "Technics," No. 2, p. 162.—ED.]

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FIG. 3.—SELF-INTENSIVE "KERN" BURNER.

to raise it to a bright red. Dr. Bunté found that at 1,200° F. (649° C) a mixture of hydrogen and oxygen in the proportion of two to one, when passed through a heated porcelain tube, combined to form water: at lower temperatures combustion did not occur. The presence of thoria in the tube had no influence upon the temperature at which the combination took place. When he passed the same mixture through a tube containing ceria, the action commenced at 600° F. (315·5° C.), and his inference was that this catalytic action localises a high temperature in the small particles of ceria spread over the surface of the inert thoria, and is the cause of the high light emissivity.

ATMOSPHERIC BURNERS.

Having briefly described the manufacture of mantles, we come to the most important feature of incandescent mantle lighting, *viz.*, the burner. This must give a non-luminous flame, or else deposition of carbon will soon ruin the mantle as regards its light-giving properties.

A non-luminous flame can be obtained, either by burning a mixture of air and gas mixed before combustion, or by burning the coal gas in so thin a sheet of flame that the air can permeate it with sufficient freedom to render it non-luminous.

The former method is now employed in nearly all systems of incandescent lighting, but the latter is used in Paris in one form of the De Mare system, in which a fringe of light-giving oxide is heated by a small, flat, non-luminous flame. The extensive use of incandescent mantles has produced many improvements in the atmospheric burners employed in conjunction with them and has led to study of the conditions necessary to obtain the best results.

It is gradually becoming realised that in order to secure the best results, the gas and air must not only be present in such proportions as to ensure perfect combustion, but the mixture must be so perfect that each molecule of combustible matter shall find itself side by side with the oxygen necessary for its combustion at the burner tip.

The simplest way of obtaining a hot, non-luminous flame from the combustion of ordinary coal gas, is by the use of the Bunsen burner. In this contrivance the coal gas issues from a small orifice into a fairly wide metal tube provided with air holes at its lower extremity. The gas mixes with the air in the tube, and the mixture ascends, and is burnt as it issues from the upper end of the tube; a fresh supply of air being drawn in through the air holes. The size of the air holes must be regulated so that a sufficient, but not excessive, amount of air is drawn in and mixed with the gas.

The air holes, and the small nipple by which the gas enters the tube, are shown in Figs. 2, 3 and 4.

The chemical action taking place in a Bunsen flame can be divided into two distinct parts.

The first occurs on the surface of the inner visible cone of the flame, where the hydrogen and hydrocarbons of the gas enter into partial combination with the oxygen of the air previously mixed with gas; thus forming a mixture of carbon dioxide and carbon monoxide, with some water vapour.

The second takes place in the outer zone,

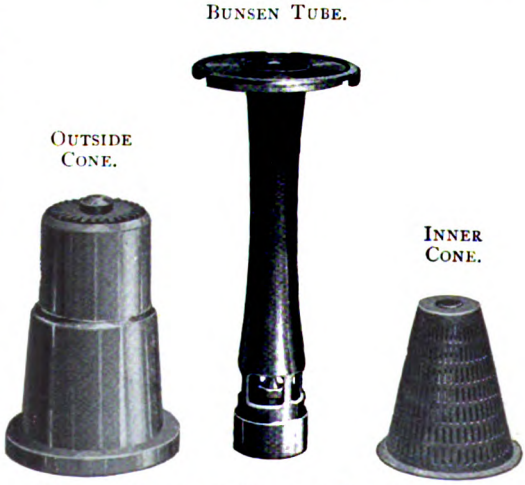

FIG. 4.—SEPARATE PARTS OF SELF-INTENSIVE "KERN" BURNER.

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and is produced by the complete combustion of the hydrogen and carbon monoxide escaping from the inner zone, the products being carbon dioxide and water vapour.

The appearance of the Bunsen flame varies with the amount of air that is drawn in with the gas before combustion takes place.

Under usual conditions the zones of the flame have a violet-blue colour, and as more air is admitted the flame grows fiercer and the inner zone acquires a green tint.

A still further addition of the air causes the mixture to become so highly explosive that it flashes back into the tube of the burner. In the Bansept and Kern burners the mixture of air can be regulated to give the greenish tint, which indicates the right mixture. This greenish tint is easily observed on the surface of the "Gauze atomisers" or mixers, through which the flame cannot flash back. These burners can be regulated for the different qualities of gas that are generally supplied; for instance, a 16-candle gas will require more air for its perfect combustion than a 14-candle gas, and so forth; providing the pressure and approximate composition are the same in both cases.

The "Kern" burner, made by the Welsbach Incandescent Gas Light Company, is represented in Fig. 3, its parts being shown separately in Fig. 4. The Bunsen tube is capped by two inverted cones, one of which is placed inside the other. The inner or "mixing" cone is pierced with numerous small apertures, in passing through which the admixture of the air and gas, which was initiated in the Bunsen tube, is completed. The outer or "suction" cone is provided with a narrow, annular, gauze-covered orifice, from which the mixture of air and gas issues, and above which this mixture is burnt. The flame thus takes the form of a hollow cylinder, coincident with the mantle. The restricted volume of the flame causes it to become intensely hot, thus raising the temperature of the mantle to the greatest possible extent; while the velocity of efflux of the gas is increased, thus drawing in a more plentiful supply of air by way of the air holes.

The Welsbach-Kern burner is a great improvement on the original "C" burner, as the lighting efficiency is increased from about 18 to 25 candles per cubic foot without any attendant disadvantages.

The following are standard sizes of Kern burner, with the gas consumption and candle-power in each case:—

No. of Burner.	Gas Consumption per Hour, in cubic ft., at 1 inch pressure.	Candle-power.
0	0·75	20
1	1·25	30
2	2·25	50
3	3·00	75
4	4·00	100

The Welsbach incandescent gas lighting is one-fifteenth the price of electric light.

The following figures given by the Welsbach Incandescent Gas Light Company, Limited, speak for themselves.

A Welsbach burner, "C" pattern with chimney, consuming $3\frac{1}{2}$ cubic feet of gas per hour, gives a light of 50 candles; and taking the year at 1,500 burning hours, the cost would be—

Price of Gas per 1,000 cubic ft.	Cost of 50-candle Gas Light for 1,500 hours.
s. d.	£ s. d.
2 6	13 2
3 0	15 9
3 6	18 4½
4 0	1 1 0
4 6	1 3 7½
5 0	1 6 3

A Welsbach burner (Kern) without chimney, size No. 2, consuming 2·25 cubic feet of gas per hour, gives a light of 50 candles, and taking the year at 1,500 burning hours, the cost would be—

Price of Gas per 1,000 cubic ft.	Cost of 50-candle Gas Light for 1,500 hours.
s. d.	s. d.
2 6	8 5
3 0	10 1½
3 6	11 10
4 0	13 6
4 6	15 2
5 0	16 10½

The carbon filament electric lamp, giving a light of 16 candles, requires about 3·75 watts per candle, or about 60 B.T.U. per 1,000 hours. Therefore, to obtain a light of 50 candles for 1,500 hours would require

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281 units, which would cost approximately—

Price per unit.	Cost of 50-candle Electric Light for 1,500 hours.
	£ s. d.
1d.	1 3 5
2d.	2 6 10
3d.	3 10 3
4d.	4 13 8
5d.	5 17 1
6d.	7 0 6

Sixty Board of Trade units give a light of 16 candles for 1,000 hours; therefore, 180 units would be required to give a light of 48 candles for 1,000 hours, and at 6d. per unit, this would cost 90*s*. With the new Welsbach burner, 48 candles are obtained with 2 cubic feet of gas per hour, *i.e.*, 2,000 cubic feet in 1,000 hours. Taking gas at 3*s*. per 1,000 cubic feet, this comes to 6*s*., or one-fifteenth the cost of electric light.

Having dealt with the Welsbach burner, we must pass on to some other intensifying and high-pressure burners now on the market. In all cases the incandescent mantle is used, the difference being in the method of increasing the pressure of the air, or the gas, or both, so as to cause a higher incandescence of the oxides of which the mantle is composed.

Amongst the best known on the market are the "Lucas Light," "The Scott Snell self-intensive gas lamp," and the "Selas system of intensified lighting by means of an admixture of gas and air."

The Lucas Lamp.

The Lucas gas lamp is made in different sizes, to give a light from 200 to 1,000 candle-power as required.

The lamp can be attached to any ordinary gas piping of sufficient size: although no special connection is required, it is advisable to use in every case an ordinary cup and ball joint; or, where there is much vibration, some suitable anti-vibrator.

No high-pressure gas main, gas compressor, or other similar arrangement is necessary, and hence the cost of an installation compares favourably with that of a high-pressure system. The lamps can be adjusted, by means of different size gas nipples, to meet the varying conditions created by variations in pressure and composition of the gas.

The cost of maintenance is proportionate to the size of the mantles and other accessories, just as in the case of ordinary incandescent burners.

The special feature of the Lucas lamp (Fig. 5) is an airtight shaft composed of—(1) the burner proper, (2) the globe, and (3) an extended metal cylinder superimposed upon the globe, all of which parts will be easily distinguished in the illustration. The high temperature attained by the metal cylinder which forms the upper part of this shaft induces a strong draught, and ensures the thorough mixture of air and gas that is responsible for the perfect combustion and consequent high temperature of the flame. No less than nine parts of air are mixed with one of gas. As a result, the record duty of 40 candle-power for every cubic foot of gas per hour is obtained. A by-pass is kept alight all the time, but out of contact with the mantle, and manipulation of the light is, therefore, reduced to pulling a chain "on" or "off."

Fig. 5.—Lucas Self-Intensive Lamp.

The cost of this light for 1,500 working hours, with gas at 3*s*. a thousand cubic feet, is £5 : 8 : 0, giving a light of 1,000 candles all the time.

The Scott Snell Intensive Gas Lamp.

The Scott Snell lamp (Fig. 6) is entirely self-contained, and can be erected on any existing column, or attached to any point to which gas is, or can be, laid on. The compressing apparatus is situated in the head of the lamp, and is actuated by the waste heat of the lamp itself. The lamp is supplied with a "Kern" burner and mantle.

The compressing apparatus acts on the air, and not on the gas: it is capable of working at any required pressure up to 50 or 60 inches of water. The supply of

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air can be regulated to suit any make or quality of gas.

The Scott Snell lamp gives a light of 600 candle power with one burner, and uses 15 cubic feet of gas per hour. Taking the price of gas at 2*s.* 9*d.* per 1,000 cubic feet, the cost is 0·82 penny per hour for gas.

The compressing apparatus consists of a closed cylinder or displacer (1) Fig. 6, within a somewhat larger containing cylinder (2), the latter being fitted with non-return inlet and outlet valves.

A spring at the head of the cylinder takes the weight of the displacer, which is thereby suspended at about mid position. A leather diaphragm (indicated by a dotted line in Fig. 6) is attached at its periphery to the framework of the lamp, and at its centre to a rod fixed to the displacer.

This, with the addition of the necessary burner, and an air reservoir to prevent violent fluctuations, completes the lamp; as an engine, it is remarkable, inasmuch as the diaphragm is the equivalent of, or at any rate admits the banishment of crank shaft, air pump, fly wheel, connecting rod, and such-like accessories which are usually found necessary to compress air.

When the apparatus is cold there is no air delivery, even if the displacer be moved by hand; but when the lower end of the cylinder is heated, the lamp is self-acting, and delivers air under pressure to its reservoir. The air below the displacer is in contact with a heated metal surface, and therefore it will expand; and if transferred to the cooler upper surface, will contract.

Expansion makes itself felt upon the diaphragm, which it distends, and thereby lifts the displacer yet higher, expelling the air above the latter and transferring it to the increasing space below it. The hitherto cool air in its turn is heated and expanded, and but for the existence of the outlet valve would cause the cylinder to burst. However, it finds relief by opening the outlet valve K, and delivering the air into the reservoir (3), and thence by the tube (22) to the burner nipple, where it applies forced draught to the burner. The initial charge of air in the cylinder is in due course exhausted, and the pressure lessens, allowing the displacer to fall from the high level it has reached. The fall is rapid and decided; the very first retrograde movement, in fact, causes some of the hitherto highly expanded air below the piston to be transferred to the cooler space above the displacer, where it is condensed, and so contributes to a further reduction in the pressure within the cylinder.

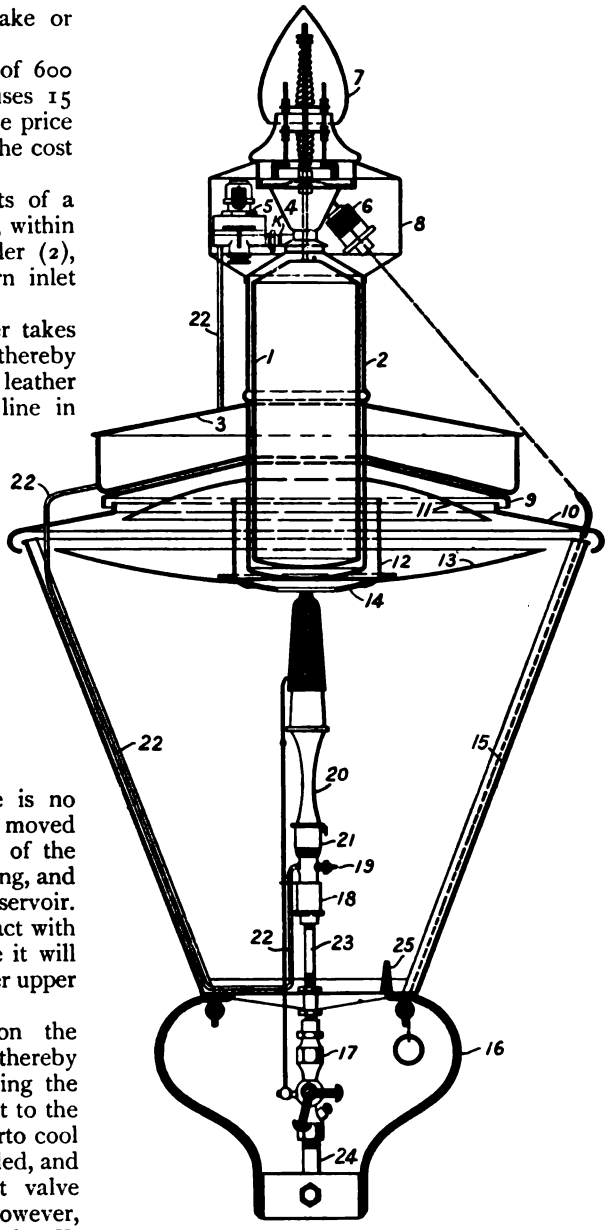

FIG. 6.—SCOTT SNELL SELF-INTENSIVE LAMP.

A decided fall of pressure is thus produced and the atmosphere presses down upon the diaphragm, thereby effectually depressing the displacer and compressing its sustaining spring. If no further air could enter, this condition would continue and produce a

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deadlock ; but an inrush of air occurs through the inlet valve, which distends the diaphragm and allows the spring to recover its normal position, carrying the displacer with it. In doing so, however, it has completed one cycle, and this very lifting movement, by transferring more air to the hot lower section, induces pressure once more, and so another cycle is started and motion is maintained. The cycle, when the lamp is fully in action, takes place in about half a second: it is automatic, and continues so long as the heat is supplied.

The cost of a light of 1,000 candles for 1,500 working hours, with gas at 2*s.* 9*d.* per 1,000 cubic feet, is £5 3*s.* 1*d.*

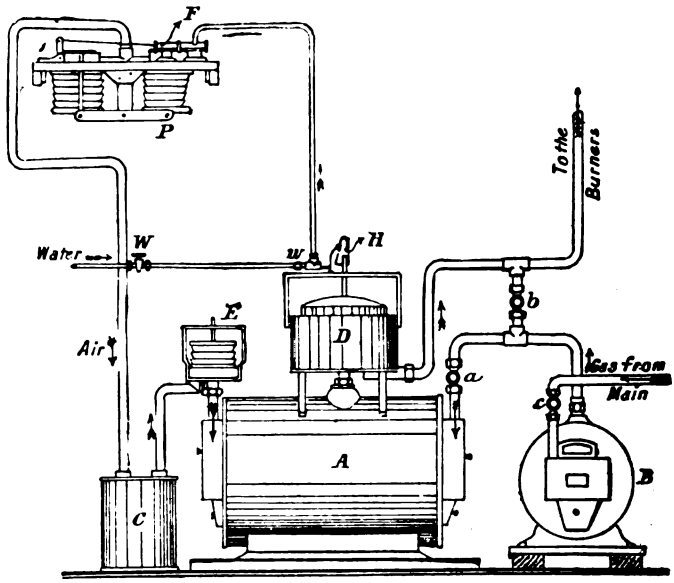

FIG. 7.—TO ILLUSTRATE THE "SELAS" SYSTEM.
(*By permission of the Journal of Gas Lighting.*)

THE SELAS SYSTEM.

The "Selas" system of intensified lighting works by means of an admixture of gas and air. In a paper read before the Institution of Gas Engineers in June, 1903, Mr. F. D. Marshall, of Copenhagen, explained his system of Intensified Lighting. The low-pressure apparatus is constructed on the principle of ensuring a constant and certain mixture of two volumes of air to one volume of gas, to be burnt under a pressure of 2 to 2½ inches: it is used in conjunction with incandescent burners, and consumes 1½, 2½ and 3 feet of gas per hour, or three times these quantities of mixture, the apparatus being, besides a mixer, a pressure raiser in a minor degree. The apparatus is made in two forms: in one, which is worked by water power, the mixing is effected in a chamber A, Fig. 7, by two drums working on a spindle (similar in construction to an ordinary wet meter), one drum (the air drum) being just double the size of the other, or gas drum.

The drums are made to revolve, not by gas pressure, but by air pressure supplied to the air drum by the bellows P, actuated by a small water motor F fed from the household service, the water required being inappreciable.

The apparatus consists of following parts :—A mixer, B consumer's-meter, C air reservoir, D mixer regulators, E air supply regulator, F water motor, H automatic water supply regulator, actuated by mixer regulators, P air pump, W water-supply tap, gas cocks and bye-pass cock. The apparatus works as follows :—On the gas and water being turned on, the air pumped through the bellows P causes the drums to revolve, drawing in air and gas in portions of two to one. When the desired pressure (about 2·0 to 2·5 inches) is raised in the drum chamber, the bell of the regulator D rises automatically, closing the water valve *w*, and the air pump immediately stops: to start again immediately the regulator bell descends, thus releasing the pressure on the arm and little wheel which close the water valve.

The apparatus once started is perfectly automatic in action, and needs no attention beyond a visit occasionally to lubricate the water motor.

There is a high-pressure apparatus on the same system, but it requires greater power to drive the combined mixer and compressor. "Selas" gas may be used with an ordinary Auer Welsbach burner by simply reaming out the gas jet and closing the air supply; or by having a "Selas" burner.

This system gives excellent results, as the following figures prove.

69 "Selas" burners of 97 candles each give 6,693 candles.

The burners in this case consume 7·9 cubic feet of mixture, or 2·65 cubic feet of gas per hour, and give 36 candles per cubic foot.

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ELECTRO-CHEMICAL AND ELECTRO-METALLURGICAL INDUSTRIES.

Part III.—Alkali and Chlorine Products.

By JOHN B. C. KERSHAW, F.I.C.

The Electrolytic Alkali Works at Chevres, near Geneva.

Introduction.

When an aqueous solution of common salt is submitted to electrolysis in an open cell, with electrodes that are unattacked by the products of the electrolytic and chemical changes which ensue, the chemical compounds sodium hydrate, sodium hypochlorite, and sodium chlorate, will all be formed in the cell; while hydrogen and chlorine gas will also be produced, and liberated in the free state. By use of special forms of cell, it is possible for the chemist to produce at will any one of these three compounds, and to suppress the formation of the other two. The electrolysis of sodium chloride has thus given birth to quite a number of more or less flourishing electro-chemical industries; and in the following pages the writer proposes to deal with these as fully as the limits of space will allow, and to illustrate the cells used in some of the more important works producing caustic soda by the electrolytic method. Over thirty electrolytic alkali works are now in operation in Europe and America: the manufacture of sodium and potassium chlorates is chiefly in the hands of the firms working the electrolytic process; and sodium hypochlorite, produced electrolytically, is proving a keen competitor of chloride of lime (bleaching powder) for bleaching purposes. These facts prove, that the processes depending upon the electrolysis of sodium chloride and its homologue potassium chloride, have grown into industries of considerable importance. Only the briefest description of the methods of manufacture employed will be possible in this article: readers of this magazine desirous of studying the individual industries more fully, may be referred to the series of handbooks,* now being published by the well-known German firm Wilhelm Knapp, of Halle, in which each separate electro-chemical industry is dealt with by an author specially acquainted with its growth and development. That industrial electro-chemistry and electro-

* *Monographien über angewandte Elektrochemie.*

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metallurgy have been deemed worthy of the publication of such a series of handbooks, is further proof of the relative importance of these new industries, and of the permanent place which they are likely to occupy in the chemical and metallurgical developments of the present century.

The Electrolytic Alkali and Bleach Industry.

If a solution of sodium chloride be electrolysed, in a cell provided with a porous diaphragm and insoluble eloctrodes, sodium hydrate is formed at the cathode, with the evolution of hydrogen gas; while free chlorine is liberated at the anode. The changes are expressed by the following equations :—

Primary or electrolytic change :—

at the cathode *at the anode*

$2\ NaCl = 2\ Na + Cl_2$

Secondary or chemical change, at the cathode,

$2\ Na + H_2O = NaOH + H_2$

The primary products of the electrolysis of such a solution are the metal sodium and free chlorine ; but the former at once reacts with the water, and produces a solution of sodium hydrate and hydrogen gas, this latter being evolved at the surface of the cathode. Should the electrolysis of the sodium chloride solution be continued in the above cell, after the sodium hydrate has commenced to form at the cathode, other electrolytic and chemical actions will occur; and the various electrolytic cells and processes which are to-day in successful operation for the production of alkali and bleach, differ merely in the means employed to confine the electrolytic and chemical changes to those represented by the above equations.

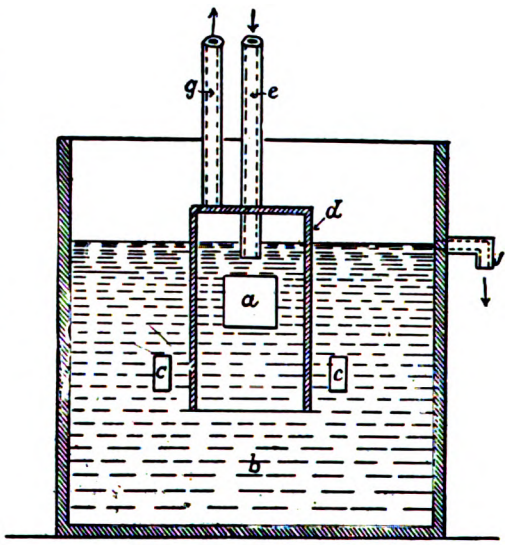

Fig. 1.—Aussig "Bell" Cell.

A very large number of different cells nave been patented, but only those in successful commercial operation will be described in this article. They are most conveniently dealt with under four classes, namely, (1) Gravity cells : (2) Diaphragm cells : (3) Mercury cells : (4) Fusion cells.

I. Gravity Cells.

In the gravity cells no diaphragm is employed, the greater density of the sodium hydrate solution formed at the face of the cathode, being utilised to cause its separation from the lighter, unaltered sodium chloride solution. The caustic alkali

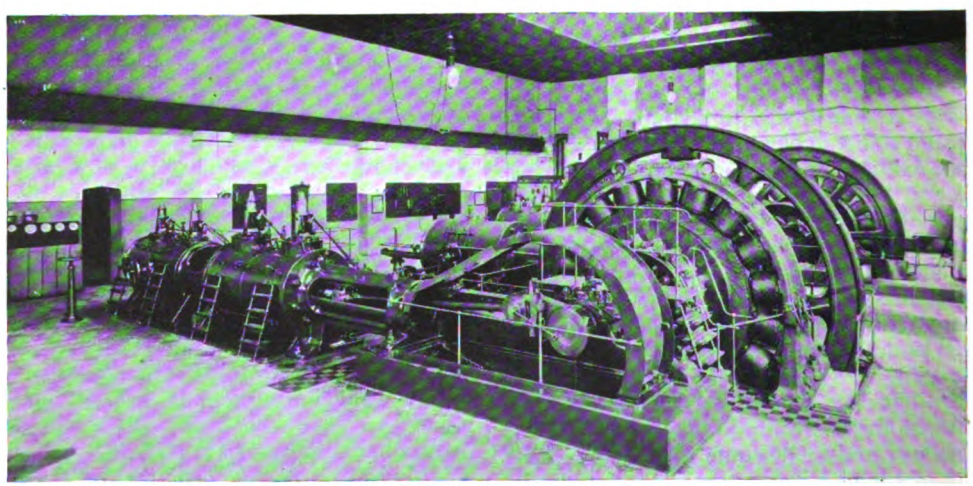

Fig. 2.—Generating Machinery at Aussig Works.

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solution thus collects at the bottom of the cell. Several of the early attempts to make use of this method of working, notably the Richardson and Holland process worked at St. Helens, failed owing to the incomplete separation of the two layers of liquid present in the cell; and at the present time the writer knows of only one cell and process of this type in successful operation upon an industrial scale, namely, that of the *Œsterreichische Verein fur Chemische Produktion*, which is worked at Aussig in Austria, and at two places in Germany.

Fig. 1 is a sectional view of the Aussig "bell" cell—*a* is the anode, *c c* are the cathodes, and *d* is the bell which surrounds the anode, and serves to collect the chlorine gas evolved at its surface.

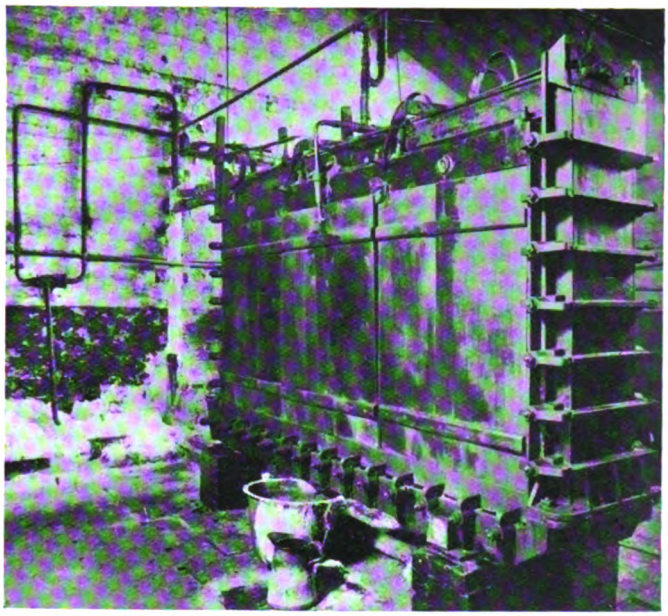

FIG. 3.—THE HARGREAVES-BIRD CELL.

The successful operation of this cell depends upon the relative positions of the anode and cathodes, with regard to each other and to the lower edge of the bell; and very careful regulation of these distances, of the flow of brine through *e*, and of the current density, is necessary in order to obtain the best possible results. Under correct working conditions, a current efficiency of between 85% and 90% is said to be obtained, and a solution containing between 100 and 150 grams of NaO_2 per litre, can be produced and drawn off from the bottom of the cell. Fig. 2 is from a photograph of the generating machinery at the Aussig works. According to a recent report 24,000 of these bell cells are in use; but as they are only of small dimensions, and work with a low current density, this number does not signify a very large output of alkali and chlorine products.

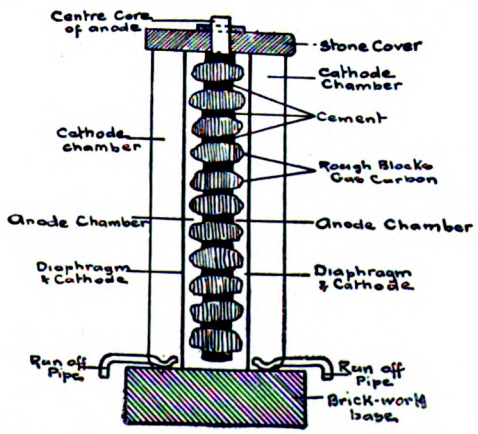

FIG. 4.—DIAGRAMMATIC VERTICAL SECTION OF THE HARGREAVES-BIRD ELECTROLYTIC CELL.

II. Diaphragm Cells.

The second method of working (*i.e.* with the aid of a diaphragm between the anode and cathode compartments of the cell) is more extensively employed; and it would no doubt become general, if the disadvantages due to the high resistance and lack of durability of the diaphragms were not considerable. The *Hargreaves-Bird*, the "*Elektron*," and the "*Outhenin-Chalandre*" cells are of the diaphragm type, and the first and last of these will now be briefly described.

The Hargreaves-Bird cell is shown in Fig. 3, which is from a photograph of the large size experimental cell worked for many months at Farnworth, near St. Helens, and inspected there by the writer in 1897. The construction of the cell may be best understood by reference to Fig. 4, which is a vertical cross section of the cell, somewhat diagrammatic in form. The inner chamber contains the anodes, which are built up from blocks of gas-carbon: it is entirely closed, and is fed with a solution of common salt, or, as at Middlewich, with natural brine from the salt beds. It is closed on each side by a porous diaphragm,

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strengthened on its outer side by iron wire gauze, which functions as cathode of the cell. The two outer cathode chambers contain no liquid beyond the condensed steam, which is blown into these chambers and removes the soda as it forms upon the surface of the wire gauze cathodes. This solution trickles down the cathodes and runs away at the base by the pipes shown in Fig. 4.

It is found to be more economical to produce carbonate of soda than caustic soda, in this cell, since the union of carbonic acid gas with the sodium hydrate at the surface of the cathode produces an additional E.M.F. which helps forward the process of separation. For this reason a mixture of steam and carbonic acid is blown into the cathode chambers of the cell. These cathode chambers, containing only steam and gas in place of any liquid electrolyte, are the distinctive feature of the Hargreaves-Bird cell; and the theory of its action is based upon the quick removal of the sodium hydrate molecules, as they form at the surface of the gauze cathode, from the further action of the electric current. The cells are made of large dimensions: 5 feet high, 10 feet long, 14 inches wide. Between 40 and 80 of these cells have now been operated upon an industrial scale for two years, at Middlewich, in Cheshire, by the *Electrolytic Alkali Company*, and 1,000 to 2,000 h.p. are employed in the manufacture by this company. The Middlewich works have not been so successful as was hoped, but this is partly due to the fall in the value of heavy chemicals since the commencement of the manufacture. Steam-power is used at this works.

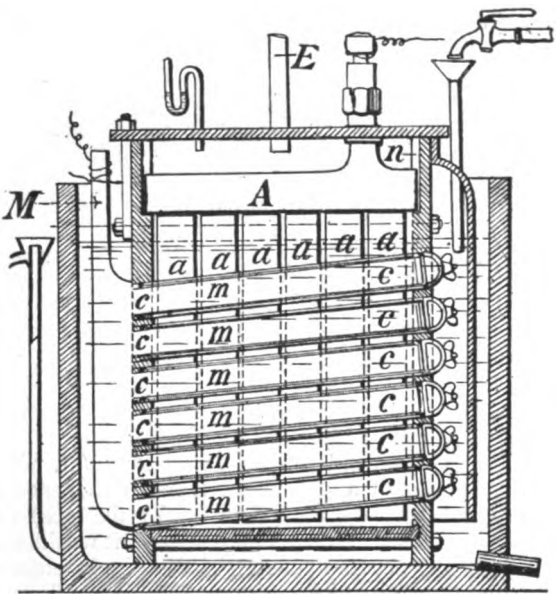

FIG. 5.—OUTHENIN-CHALANDRE CELL.

The Outhenin-Chalandre Cell.—This diaphragm cell differs essentially in construction from the Hargreaves-Bird type of cell, since a liquid electrolyte is present on both sides of the diaphragms, and the latter are made in the form of porous tubes.

Fig. 5 is a sectional elevation of the cell; and in this *c c c*, . . . represent the diaphragm tubes: A, the anode bus bar, and M, the cathode bus bar, for the attachment of the electrodes. Flat carbon anodes *a a a*, . . . extend *between* the diaphragm tubes, as shown by the dotted lines, into the brine contained in the closed anode chamber of the cell; and the current is led away from the *interior* of the diaphragm tubes *c c c*, by *m m m*, projecting lugs or teeth of the iron cathode bar M: these teeth extend along the interior of the tubes, and serve to collect the current.

The caustic soda solution, which forms at the surface of these cathodes, flows by gravity down the interior of the inclined tubes, and collects at the bottom of the outer cell; while the chlorine gas is led away from the closed anode chamber, by the exit pipe E. The Outhenin-Chalandre cell appears very complicated in construction, but good results are said to have been obtained with it; and it is now in operation upon an industrial scale at Chevres, near Geneva, and at two other localities in France and Italy. The figure at the head of this article is from a photograph of the works at Chevres, and it shows how wonderfully clear the atmosphere is, in the neighbourhood of this modern alkali works. The Chevres works draws its electric power from the Chevres water-power station on the Rhone.

The "Elektron" Cell.—The "*Chemische Fabrik Griesheim*" *Elektron* were the first chemical manufacturers to produce alkali and chlorine by electrolytic methods upon an industrial scale of operations; but although their process has now been worked for over ten years at Griesheim, near Frankfort, in Germany, very few details concerning it have been allowed to appear in print. There are grounds for believing, however, that it is a diaphragm process; and that the difficulties met with by other inventors in obtaining diaphragms that would prove durable, under the conditions obtaining in an electrolytic alkali cell, were early surmounted

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by the Griesheim Company. The "Elektron" cell and process are employed, not only at Griesheim, but also at seven or more subsidiary works in Germany, France, Spain and Russia. No very trustworthy figures have been published, however, showing the total h.p. now being utilised by these works in the production of alkali and bleach.

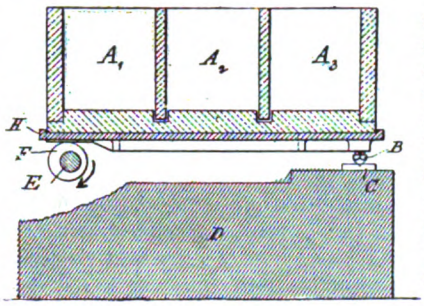

FIG. 6.—THE CASTNER MERCURY CELL.

III. Mercury Cells.

In this type of cell, advantage is taken of the property of mercury to form an alloy (or amalgam) with sodium, liquid at ordinary temperatures: the sodium liberated at the surface of the mercury cathode is thus at once removed from the further action of the current.

The conversion of the sodium, alloyed with the mercury, into sodium hydrate, is very simply effected by treating the amalgam with water; and a solution of sodium hydrate is then obtained, with restoration of the mercury to its original condition, ready for use again in the cell. A very large number of mercury cells have been patented, the principle of all being the same, variations only being seen in the mechanical and other devices, introduced for causing the regular circulation and decomposition of amalgam obtained in the cathode compartment of the cell. Only three forms of mercury cell are known, however, to be in operation at the present time:—the *Castner-Kellner*, the *Solvay*, and the *Bell*. These will now be briefly described.

The Castner-Kellner Cell.—The circulation of the mercury and amalgam in this cell is brought about by a rocking movement imparted to the cell by an eccentric placed under one end of it, the other end being pivotted to a fixed support. Fig. 6 is a diagrammatic section of the original Castner cell. The cell is constructed of slate, and is divided into three compartments as shown; the divisions between these being in the nature of hanging walls, which dip into the mercury lying on the floor of the cell. The solution of brine lies above the mercury in the end compartments of the cell; graphite anodes dip into the brine. The mercury functions as cathode, and the middle compartment of the cell contains water. On completing the electrical circuit, chlorine gas is liberated in A_1 and A_3, and is conducted away, while sodium passes into the mercury on the floor of the cell. By the rocking motion of the cell the

FIG. 7.—CELL ROOM AT CASTNER-KELLNER WORKS, WESTON POINT, ENGLAND.

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amalgam is transferred to the middle compartment A_2, where it meets with water and produces sodium hydrate. The Castner cell has proved very successful in industrial operation, and the only improvement effected upon the original design is in the utilisation of the E.M.F. produced by the decomposition of the amalgam with water, in the cathode chamber of the cell. This improvement was suggested and patented by Kellner, and is attained by using iron cathodes in the middle compartment, and by making the mercury an intermediate (or secondary) electrode. The Castner-Kellner cell and process are worked on a large scale at Weston Point, near Runcorn, in this country; and at Niagara

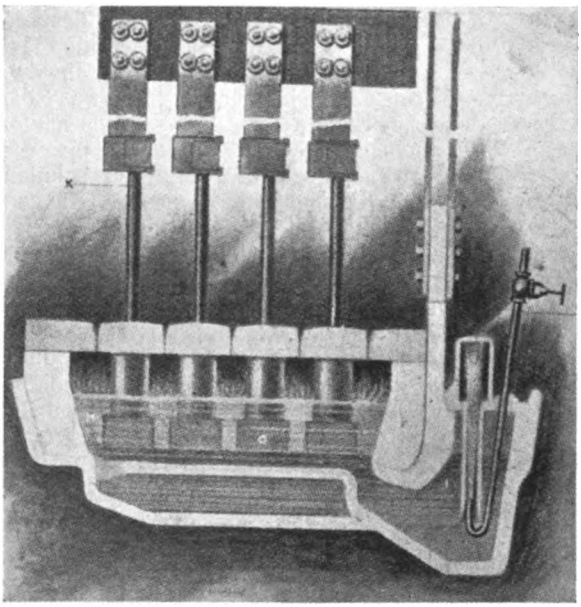

FIG. 8.—ACKER FUSION CELL.

Falls in America. These two companies have, hitherto, been the most successful of the electrolytic alkali companies in England or America. About 10,000 h.p. are utilised in these two works in the production of alkali and bleach. Fig. 7 is from a photograph of the Weston Point works.

The Solvay Cell.—In this cell, advantage is taken of the fact that sodium amalgam is lighter than mercury, and floats upon it as a kind of crust or scum. The separation of the amalgam from the mercury is, therefore, effected by constructing the cell with a movable bridge or weir about two inches in height, across one end; and by causing a flow of mercury in the direction of this bridge, from one end of the cell to the other. The amalgam is carried over the bridge, and is decomposed with water in a separate vessel; while the surface of the mercury on the floor of the cell is kept clean and sufficiently free from crust, to function properly as a cathode. The Solvay mercury cell and process are operated at Jemeppe, in Belgium, and at Donetz, in Russia; but neither of these works is large. Steam-power is employed in both cases.

The Bell Mercury Cell.—This cell must not be confused with the Aussig "bell" cell already described, in which the term "bell" is employed to indicate the shape and character of the anode compartment of the cell. The "Bell" mercury cell is named after the inventors, Messrs. Bell Bros., of U.S.A. In this cell, the pressure of the chlorine gas liberated in the anode chamber is utilised to cause the circulation of the mercury, which is essential for the proper working of the mercury type of cell. Limits of space will not permit the details of cell construction to be described in this article. The Bell mercury cell is operated by the Pennsylvania Salt Company at Wyandotte, Mich., but the developments of this process are stated to be yet somewhat restricted in character.

IV. Fusion Cells.

In this type of cell, the *fused* salt is employed as electrolyte, in place of being utilised as an aqueous solution; and molten lead is used as cathode, a lead-sodium alloy being formed. Certain economies are effected, by employing the salt in the fused state. In the first place, very high current densities can be employed with safety in the decomposing pots, and consequently a high output can be obtained from a comparatively small plant. This reduces the capital outlay upon plant. In the second place, the evaporation of dilute caustic alkali solution is avoided, for the caustic lye can be obtained of any desired strength, from the lead-sodium alloy, in one operation at the final stage of the process. Thirdly, where rock-salt is available, the solution of this and pumping of the brine is rendered unnecessary, and the cost of raw material is therefore reduced.

The disadvantages of the fusion processes for the production of alkali and bleach by electrolysis, are those due to the increased wear and tear on the decomposing plant, and

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to the destructive character of molten salt and hot chlorine gas. However, these have been surmounted; and two processes of this character have been worked industrially—the Hulin and the Acker processes.

The Hulin Fusion Cell.—The special feature of the Hulin cell was a secondary lead anode, this being used to obtain lead dissolved in the fused salt, both lead and sodium being then deposited at the surface of the cathode; in this way, a more regular production of the lead-sodium alloy takes place. A definite percentage of the total current passing through the cell was shunted through this secondary lead anode; and the proportion of lead being produced hourly at the cathode could be varied at will. The Hulin cell and process were operated for some time with 1,000 h.p. at Les Clavaux, in France, about 1898; but the financial success of the process was in doubt, and the power at this works has now been devoted to other electro-chemical manufactures.

The Acker Cell and process.—The distinctive feature of the Acker cell is the use of a steam-jet, to cause circulation and decomposition of the molten lead-sodium alloy, obtained in the cathode compartment of the cell. Fig. 8 is a diagrammatic section of this cell; K being one of the anode bars, which are connected to the graphite anode blocks dipping into the molten sodium chloride; I is the molten lead-sodium alloy which functions as cathode.

The steam jet and circulation chamber are shown on the right of this diagram. By regulating the steam supply, it is stated that caustic soda of any desired strength up to 74% can be obtained from the cell. The lead, after removal of the sodium in the form of hydrate by the action of the water, returns to the floor of the cell and functions anew as cathode.

The Acker cell and process have been operated industrially at Niagara Falls for some years, and the works are stated to have been very successful. Fig. 9 is from a photograph of the Niagara factory of the Acker Process Company.

Summary.

As already stated, over thirty Electrolytic Alkali works are now in operation in Europe and America, and between 40,000 and 50,000 h.p. are employed in this manufacture. In some cases, especially in Germany, the potash salt is employed as raw material in place of sodium chloride, and caustic potash is thus produced in place of caustic soda. The chlorine liberated at the anode is most usually employed for producing bleaching powder ("bleach," or chloride of lime) by the ordinary process of absorption by hydrate of lime in lead chambers; but latterly one or two works have commenced to use it for other purposes, on account of the low prices ruling in the bleach market. The manufacture of carbon-tetrachloride and of pure hydrochloric acid are the most interesting of these new developments; the latter being produced by burning the chlorine, in the hydrogen obtained from the cathode compartment of the Outhenin-Chalandre cell. Since many millions of cubic feet of hydrogen gas are at present annually wasted by the electrolytic alkali works, there would appear to be an opening for some further applications of this gas, along the lines of the process now being worked at Bussi in Italy, for manufacture of pure hydrochloric acid.

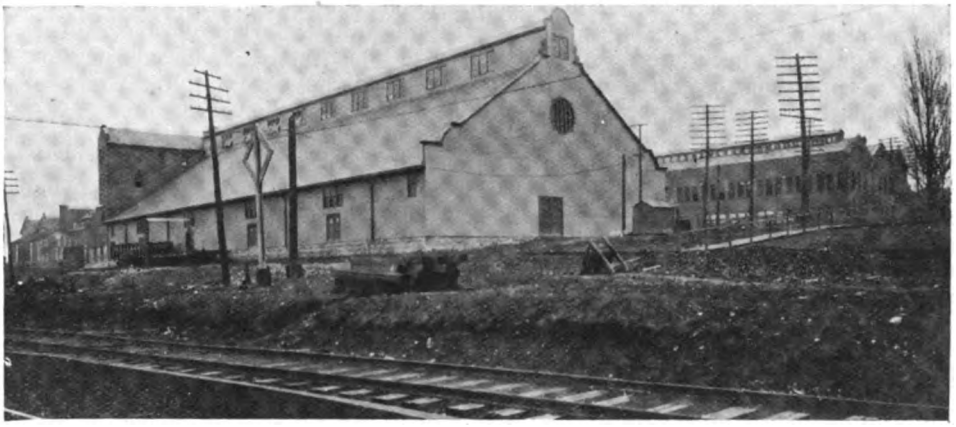

Fig. 9.—Works of the Acker Process Co., Niagara Falls.

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The Electrolytic Hypochlorite Industry.

Referring to the chemical equations given on p. 546, it will be seen that when a solution of sodium chloride is electrolysed in a diaphragm cell, using insoluble electrodes, sodium hydrate, hydrogen, and free chlorine gas are produced, as end products of the primary and secondary reactions in the cell.

If now this sodium hydrate be allowed to react with the chlorine within the cell, at a temperature below 20° C, sodium hypochlorite will be produced, in accordance with the following equation :—

$$6\,NaOH + 3Cl_2 = 3\,NaOCl + 3H_2O + 3\,NaCl.$$

Sodium hypochlorite can therefore be produced electrolytically, by decomposing sodium chloride under certain conditions; chief of these being, that the cell must be of the non-diaphragm or "open" type: that the electrodes must be close together; and that the temperature must not exceed 20° C. If this limit of temperature be exceeded, chlorate will be produced, as will be described in the next section of this article.

Since sodium hypochlorite is a valuable bleaching agent, a large number of cells have been patented for its electrolytic production; and a fair number of these have received industrial trial and are now in commercial use.

However, the electrolytic bleaching industry has not developed so rapidly as was at one time hoped, since hypochlorite of lime (bleaching powder, or *Bleach*, as it is called in the trade) is still the cheaper bleaching agent, at the present market prices of this chemical; and the use of sodium hypochlorite is confined to those industries where the absence of lime in the bleaching solution is a distinct advantage, or to localities where the industrial conditions favour the installation of an electrolytic plant. The rapid development of the electrolytic alkali and bleach industry during the last ten years has served to handicap the progress of electrolytic bleaching, since hypochlorite of lime is now selling at £4 5*s*. per ton as compared with £6 10*s*. a few years ago; and it has recently been as low as £3 10*s*. 6*d*. per ton. This fall in the price of bleach in recent years has been chiefly due to the competition of the bleach made in the electrolytic alkali works, with that produced by the Le Blanc process; but it has not favoured the development of the allied sodium hypochlorite industry, and it is now reacting unfavourably upon the progress of the electrolytic alkali industry itself.

Electrolytic cells for the production of hypochlorites have been patented in the names of Hermite, Kellner, Schuckert, Vogelsang, Corbin, Haas and Œttel, Tailfer, Atkins and others. They are all distinguished by certain common features, namely:—absence of a diaphragm, electrodes of grid type placed near together, rapid circulation of electrolyte; all these being designed to promote the conditions which favour the formation of hypochlorite in the cell. In most cases, an alloy of platinum and iridium is employed as electrode material, since this alloy is unattacked by the chlorine and oxygen compounds formed at the anode; but Haas and Œttel, in their earlier cell, adopted graphitised carbon electrodes. Fig. 10 shows the general appearance of the Kellner cell. The electrolysis of the salt solution is carried out in the vessel A; B and C being the two sets of grid-type electrodes, placed parallel with one another and fairly close together in the electrolyte. D is a large earthenware vessel which serves as a container for the salt solution to be electrolysed, and for the hypochlorite solution when formed; and E is a small pump of special construction, which is used to cause circulation of the electrolyte. When hypochlorite solution is required, D is charged with water and the requisite amount of common salt, the pump E is started, and current is passed through A by way of the electrodes B and C, until the solution in D contains the desired amount of active chlorine. Since hypochlorite of soda is itself decomposed by the electric current, only low percentages of this substance can be obtained practically: and high percentages are always gained at the expense of the efficiency of the process. Recent improvements in some working details have, however, led to a partial removal of this difficulty, and highly concentrated hypochlorite solutions have recently been obtained without marked loss of current efficiency.

The most notable installations of electrolytic bleaching plant are to be found in France, Germany and Sweden, Messrs. Corbin & Cie. having a 700 h.-p. installation of their own hypochlorite cell at Lancy, Isère. In this case the solution is used for bleaching wood-pulp and cellulose.

In America, installations of a somewhat similar character are to be found in connection with the paper-pulp factories. Across the Atlantic, however, the tendency is to electrolyse sodium chloride in a diaphragm type of cell, and to absorb the liberated chlorine in a separate vessel, either in the caustic soda lye obtained from the cell, or in

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milk of lime. In the latter case, the caustic soda solution is run away as a waste product, since it is considered it would not pay to purify it from the undecomposed salt, and to obtain solid caustic soda.

According to Professor Haber, who has recently inspected some of these plants, this method of working is more suited to the conditions obtaining across the Atlantic than the method adopted in Europe.

FIG. 10.—KELLNER HYPOCHLORITE CELL.

THE ELECTROLYTIC CHLORATE INDUSTRY.

As already stated, if the free chlorine produced at the anode, in an open cell fed with a solution of common salt, be allowed to react with the sodium hydrate produced at the cathode, at a temperature above 20° C., chlorate of soda will be produced. The change is expressed chemically by the following equation :—

$$6\ NaOH + 3\ Cl_2 = NaClO_3 + 5\ NaCl + 3\ H_2O.$$

According to this older theory, chlorate is formed in the electrolytic cell as the result of a secondary chemical reaction between the primary products of the electrolysis—chlorine and sodium hydrate.

In recent years, however, a large amount of research work has been carried out by German electro-chemists upon this subject; and it has been proved that the formation of chlorate in the electrolytic cell is less simple than the above equation would lead one to suppose. Limits of space will, however, not permit the writer to give any detailed account of this work, or of the conclusions based upon it, in this article.

The cells patented for the production of chlorate by electrolysis follow, in their general design, those planned for hypochlorite production; facilities for the reaction between the anode and cathode products must be provided, but the necessity for rapid circulation in order to keep down the temperature is, of course, absent in the case of chlorates. The electrodes are, in all cases, of platinum-iridium alloy and are placed fairly close together; a high current density is employed, in order to obtain the desired temperature of between 60° and 70° C. in the cells, without recourse to external heating. The cells now being worked upon an industrial scale, are patented in the names of Gall & Montlaur, Corbin, Gibbs, Carlsen, and Hurter, and between 30,000 and 40,000 h.p. are being employed in the manufacture. The industry has, in fact, suffered from its own success, and the selling price of chlorates has fallen to such a low point that little inducement now exists for the electrolytic manufacturers to extend their works, or for financiers to build new electrolytic factories.

From 6*d.* per lb. (the price of potassium chlorate in 1890, when the electrolytic process was first worked industrially) the price has fallen to $2\frac{5}{8}d.$, and the sodium salt, which at one time was at least 2*d.* per lb. dearer than the potassium salt, can now be obtained for practically the same price. This striking fall in price is chiefly due to the rapid progress of the electrolytic works, and to the competition between the producers by the old Liebig and the newer process. The annual production of chlorates by the electrolytic works is estimated to be at present between 7,000 and 10,000 tons per annum, and to be two-thirds of the total world production of this chemical.

The largest installation of electrolytic plant for the manufacture of chlorates is to be found at Chedde in the Haute Savoie, where Messrs. Corbin & Cie. have a factory utilising between 7,000 and 10,000 h.p. in this

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manufacture, and producing 3,000 to 4,000 tons of chlorate per annum. Fig. 11 is from a photograph of the Chedde works, which is a notable example of the development of chemical industry in a region far from coal; for the Chedde factory is situated almost under the shadow of Mt. Blanc and exclusively utilises water-power.

Other electrolytic chlorate works are operated at St. Michel in France: at Valorbes in Switzerland: at Mansboe in Sweden; and at Niagara Falls and Bay City in U.S.A. The latter is the only electrolytic chlorate factory operated by steam-power, and it was promoted and built by the North American Chemical Company, a subsidiary of the United Alkali Company of Liverpool.

FIG. 11.—GENERAL VIEW OF THE CORBIN CHLORATE WORKS, CHEDDE.

The chlorate manufactories at St. Michel and Valorbes are the most interesting of the remaining works, since they are owned by the *Société d'Électro-chimie* of Paris, the pioneer company in this industry. The cell and process worked at these two factories was patented by two French engineers, Messrs. Gall & Montlaur, in 1887, and these two gentlemen have recently received from the French *Académie des Sciences*, the Kastner-Bonsalt premium and medal for their services to industrial progress. It is interesting to note, however, that Charles Watt, in the Patent No. 13,755 of 1851 (which has already been alluded to in the second article of this series as the master-patent of the electro-chemical and electro-metallurgical industries) distinctly laid down the conditions which must be fulfilled in order to obtain potassium or sodium chlorate from the chlorides in the electrolytic cell. Messrs. Gall & Monlaur's services to industrial progress lie, not so much in the re-discovery of the process, as in proving that it could be made to pay when worked upon a large scale.

In the early day of the electrolytic chlorate industry, it was customary to produce only potassium chlorate, since this salt is much less soluble in water than the sodium salt, and its separation from the unaltered chloride was obtained by cooling and crystallisation of the cell liquors, and was therefore a comparatively simple operation. The electrolysis of potassium chloride was carried on in the cell until chlorate crystals commenced to separate. The solution was then run off and the chlorate allowed to crystallise out by cooling in a second vat. Latterly, however, owing to the keen competition in this industry, the manufacture of sodium chlorate, which commands a higher price, has been taken up, and considerable success has been met with in improving the process and in reducing the costs of manufacture of this salt by the electrolysis of sodium chloride solutions.

The general efficiency of the electrolytic process for chlorate production has also been greatly increased in recent years by applying in the works the information and results

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obtained by the laboratory investigations referred to at the commencement of Section III. of this article; and there is probably no other electro-chemical industry at the present time in which such progress can be shown. Messrs. Corbin & Cie. have recently informed the writer that they have practically doubled the output of chlorate at their works at Chedde (*i.e.*, raised it from 2,200 to 4,000 tons per annum) by careful attention to the scientific side of the process; and there is little doubt that the other manufacturers engaged in this industry are equally alive to the importance of keeping themselves acquainted with the results of laboratory researches bearing on their industry. The necessity for a close alliance between science and industry, as a condition of progress and development, is, in fact, well exemplified in the electrolytic chlorate industry; and its rapid growth from the humble position occupied by it in 1890, is an object-lesson to other industries exemplifying the practical value of scientific research and laboratory investigation.

RECENT RESEARCHES ON RADIO-ACTIVITY.

The Composite Character of Thorium

THE suggestions that have recently been made to the effect that thorium is not a simple element, but a mixture, are by no means altogether novel. As long ago as the Toronto meeting of the British Association, Brauner stated that he had obtained evidence of the composite character of the material, and recent investigations have not thrown much more light on the nature of the constituents.

The Radio-activity of Thorium dependent on its Association with Uranium

ONE of the most striking of the recent observations in connection with thorium is that of Hofmann and Zerban, who have shown that the radio-activity of the element is largely dependent on its association with uranium in the mineral. As the observations are of some interest, and appear to have been very generally overlooked, it may be of interest to quote the table which shows the dependence of the initial activity of the thorium on the percentage of uranium in the mineral.

Mineral.	U_3O_8 %	ThO_2 %	Initial activity.
Bröggerite .	78	15	Very strongly active
Cleveite ...	70	7	,,
Euxenite ..	5-11	Very little	Very active
Samarskite.	4-17	4	,,
Fergusonite	1·5-7	1-3	Feebly active
Xenotim ..	0·5-3·5	0·5-3·5	,,
Thorite ...	10	50	,,
Orangite ..	1	72	Very feebly active
Aeschynite.	0·31	16	,,
Monazite ..	0·1	1-2·5	,,

After one-and-a-half to two years the activity was reduced in each case to a value not much greater than that of the uranium salts, but initially the more active samples were at least ten times as active. The question of whether the activity might not be wholly due to association with uranium was tested by examining thorium separated from uranium-free samples of the Norwegian minerals orthite, yttrotitanite and gadolinite. The separated thorium proved to be possessed of no measurable activity, and no mention is made of any subsequent development of radio-active properties.

Berzilium and Carolinium

ACCORDING to press reports recently received, Professor Baskerville has isolated two new elements from crude thoria by the action of chlorine and carbon, and has named them Berzilium and Carolinium, in honour of the Swedish chemist Berzelius, and the State of North Carolina, in which Dr. Baskerville holds his professorship. At present no details are to hand, and it would be premature to discuss the elementary character of the substances isolated. It is stated, however, that the new elements are radio-active in character, and it is not impossible that the associated elements to which the thoria owes its activity have been distilled out in the form of volatile chlorides, as might well be the case if they should prove to be members of the aluminium group of elements.

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POTTERS' MATERIALS.

PART II.

By WILTON P. RIX, late Manager of Messrs. Doulton's Art Pottery, Lambeth.

CLASSIFICATION OF CLAYS.

THE clay deposits vary so greatly in condition and composition, that it is extremely difficult to group them in classes having definite characteristics. Moreover, the distinctions which satisfy the geologist are of little importance to the potter, with whom scientific classification is of little value. A ceramic classification is therefore needed.

The broad distinction of kaolins and clays, already referred to, may be sufficient for general purposes. The clays again may be usefully grouped on the basis of their fusible qualities, thus :—

1. *Fusible Clays.*—Those which collapse and lose form at low temperatures.
2. *Vitreous Clays.*—Those which vitrify but retain their forms.
3. *Refractory Clays.*—Those which withstand high temperatures, and do not vitrify.

A further and important form of classification may be based on the high proportion of certain ingredients present in the clay. Thus the clay may be characterised as :—

(*a*) Alkaline ;
(*b*) Siliceous ;
(*c*) Ferruginous ; and
(*d*) Calcareous.

It will be understood that clay deposits may fall under more than one of these classes, which may be subdivided thus :—

Alkaline kaolins.	Alkaline clays.
Siliceous kaolins.	Siliceous clays.
Ferruginous kaolins.	Ferruginous clays.
Refractory siliceous clays.	
Plastic calcareous clays.	

Space does not permit me to give details of clays falling under these various headings : they can, however, be readily classified on reference to their chemical analyses, in conjunction with a physical examination.

While it is true that clay, owing to its plastic properties, forms the chief and indispensable ingredient of pottery bodies, it is also equally true that, without the admixture of other materials, pure clay is practically useless to the potter.

Various properties are wanting in pure clay, which are necessary for obtaining successful results. Certain other materials, possessing such properties in a marked degree, have been discovered by potters ; and these are added as required.

In some instances clay deposits are found naturally containing such qualifying ingredients, in proportions specially suitable to the purpose of the manufacture in hand. These clays can be used in their natural condition. There are, however, a far larger number of clay deposits which need the addition of one or more foreign ingredients to improve their working qualities.

In the making of fine pottery the number of foreign materials compounded with the clay substance is extensive. They may be classified in various ways. The simplest system, however, is based on the properties imparted to the mixture, thus :—

CLAY SUBSTITUTES.

Among these may be placed all materials which, though not possessing all the characteristics of clay, are nevertheless similar in some respects, and may for certain purposes be substituted for a portion, or at times for the whole, of the clay contents.

These materials are similar to clay, so far that they all contain greater or smaller proportions of hydrated silicate of either alumina or magnesia ; and possess, in a limited degree, the essential properties of plasticity and hardening under heat.

The adoption of materials of this class is somewhat exceptional, being chiefly limited to districts in which they are plentiful. Among these materials, the following may noticed :—

(*a*) *Cimolite.*—A stony material, somewhat friable, to be found in some quantity in the

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Ionian Isles, notably in Cimolus, where it is used for pottery purposes. It is also found in India and some parts of Russia.

It is of a light grey, white or reddish colour; sometimes of a slaty nature, and very soft. Its formula may be given as

$$4\ Si\ O_2,\ Al_2\ O_3,\ nH_2O.$$

It is composed as follows:—

Silica . .	62·30
Alumina . .	24·11
Iron oxide .	1·25
Water . .	12·34

(*b*) *Allophane.*—This is a material, either brown, light green, light blue, yellow, or colourless, much less siliceous than the above, and found in the United States at Utah, also at Saint Antoine, in France. It usually occurs mixed with kaolinite in connection with other clays. Its formula may be approximately stated as:—

$$Si\ O_2,\ Al_2\ O_3,\ nH_2O$$

Its composition, which is variable, is stated to be similar to collyrite, as follows:—

Silica . .	59·00
Alumina . .	22·00
Water . .	26·00

It sometimes, however, contains a little lime. Its specific gravity is 1·87.

(*c*) *Collyrite.*—This is a variety, almost identical in composition with the above. It was first found at Saint Sever in France: in the Pyrenees, and in Saxony. It also occurs in the upper chalk, near Brighton, varying greatly in physical structure. It is greasy in character, and white.

(*d*) *Halloysite.*—This is a substance similar to kaolin, of an oily and plastic nature, white in colour, occasionally employed in porcelain manufacture. It varies considerably in colour and in composition. The compositions of various samples are given below:—

Silica . . .	39·90	44·94	41·30
Alumina . .	24·00	39·06	47·80
Oxide of iron .	—	—	trace
Lime . . .	10·10	—	0·84
Alkalies . .	—	16·00	0·76
Water . . .	26·00	—	9·30

It occurs occasionally in granite beds or in ores, and is sometimes translucent.

(*e*) *Lenzenite.*—This is a similar material, being a variety of the above, and is sometimes used in refractory mixtures, though without sufficient reason. It is found in Haute Vienne, in France, at Call in the Eifel, and other places. Its composition is as follows:—

Silica . .	30·00
Alumina .	36·00
Oxide of iron	1·95
Magnesia .	0·18
Alkalies . .	0·50
Water . .	21·50

(*f*) *Magnesite.*—In addition to the above-named silicates having an aluminous base, there are those in which the alumina is replaced by magnesia, of which magnesite is an example.

This material, which is hard, amorphous, and in some cases very white, is found in the Island of Eubœa; also in Spain, near Madrid. It has been used in the manufacture of both porcelain and earthenware, also in the manufacture of refractory bricks.

The following is an analysis of Spanish magnesite:—

Silica	54·0
Magnesia	24·0
Water	20·0

(*g*) *Steatite.*—A rocky material, soft and somewhat friable, occasionally used in making large ware on the Continent. Its composition varies as under:—

Silica . .	61·75 .	63·00
Magnesia .	35·00 .	31·65
Iron oxide .	1·25 .	—
Water .	2·00 .	4·90

(*h*) *Talc.*—This is similar to the above in composition, its formulæ, when pure, being $4\ MgO,\ 5Si\ O_2,\ nH_2O$.

(*i*) *Gioberite.*—In addition to the above magnesium silicates, a rocky substance of a refractory nature, called gioberite, has been used for both porcelain and refractory goods. In composition it consists of magnesium carbonate, usually mingled with a small quantity of magnesium silicate.

It is to be understood that, although the above materials are used in certain instances, and, therefore, merit mention here, their adoption is, as a rule, local, or for economic or specific purposes only; so that they do not hold any important position as clay substitutes.

Non-Plastic Materials.

The non-plastic materials may be divided into four classes, as under:—

1. Those added for reducing *plasticity*, such as flint, sand, lime, and grog.

2. Those added for *increasing fusibility*, such as felspar, Cornish stone, boracic and alkaline frits; also calcareous earths, such as chalk, marble and gypsum.

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3. Those added to *reduce fusibility*. These include the refractory materials, such as quartz, flint, sand, gannister and bauxite.

It is necessary to observe that these materials also reduce plasticity, and may, in certain circumstances, be introduced for both purposes.

It should be noticed that certain materials not mentioned above, such as lime and magnesite, as well as silica, though themselves highly refractory when used alone, may not, under certain conditions, when mixed with other materials, render them more refractory.

4. *Carbonaceous materials*, which disappear in the burning. These are added to open the clay bodies for various purposes :—

(*a*) To increase porosity.
(*b*) To increase lightness.
(*c*) To reduce shrinkage.
(*d*) To increase binding quality of body.
(*e*) To hasten drying.

Such materials are sawdust, straw, peat, coal or coke dust, lignite, cinders, ashes.

Estimation of Quality of Raw Materials.

The control of results in the manufacture of clay goods is absolutely essential in order to obviate loss. Unfortunately, the natural deposits of clay and of all pottery materials vary constantly in their qualities and composition. Hence unremitting watchfulness is essential, and the methods of estimating quality assume a position of considerable importance in the manufacture.

Two distinct branches of enquiry are needed, *viz.*:—that relating to *chemical composition;* and that relating to *physical condition.*

The first is discovered by *quantitative chemical analysis*.

The second forms the subject of *mechanical tests*, conducted by different methods, according to the object in view.

Analysis alone is of limited value unless associated with other methods; it fails to reveal the physical condition of the various elements present in the mass, nor does it show how these are chemically combined.

Thus an ordinary chemical analysis may show that a sample contains stated portions of silica, lime, magnesia, and alumina; but it does not make clear how much of the silica is combined with the other materials, and how much is in a free state; neither does it show the proportions of combined silica associated with either of these bases. Finally, it does not show whether the free silica present is in large or small particles, or is in a crystalline or amorphous state.

All these points are important to successful manufacture.

It is not here proposed to deal with the chemical analysis of clays and materials; but it may be noticed, in passing, that the comparison of analyses for the purpose of ascertaining the relative value of clays, etc., requires some care. It is important that the analyses should be based on the same method of working.

Some analyses give percentages based on the material as received, and include moisture at ordinary temperature; while others, more correctly, show the percentage after moisture is dissipated at 100° C. Others, again, give the percentage after firing; that is, after the combined water has been eliminated. Though the actual contents of silica or alumina may be the same in these analyses, the figures obtained by the respective methods will vary considerably.

In estimating the properties of clay from the chemical analyses, the following points should be noted :—

(*a*) *The contents of silica* do not indicate the refractory qualities of the clay with any certainty, unless their physical condition is also known: *cæteris paribus*, the higher the silica contents, the more fusible the clay; but if less than 9·17 per cent. of alumina is present, fusibility decreases again.

(*b*) *The contents of hydrosilicate of alumina*, in proportion to the other materials, give approximate indication of the plasticity of a clay. But it must be noticed that the structure of the particles has considerable influence on plasticity; and also the size and nature of the other particles of the mass.

It is, therefore, impossible to form accurate conclusions respecting plasticity, by any other means than direct mechanical tests. Manipulation with the fingers, and estimation by cohesion and by touch, though apparently simple, are, in experienced hands, the most trustworthy means of ascertaining the degree of plasticity.

Such methods, however, form no adequate means of comparison.

(*c*) *The contents of alkalies, alkaline earths, and ferrous oxide* will afford some indication of the fusibility of a clay. But the larger the size of siliceous particles, associated with them in the mass, the more the fusibility is *reduced:* and the greater the variety of the fusible ingredients, the more the fusibility is increased, although the total fusible contents may be the same.

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(*d*) *The density of a clay* will give some clue to the proportion of *silica* present. Silica has a density of 2·6 or 2·7, whereas that of clay bodies varies from 2·4 to 2·5, and this difference is easily perceptible in handling clays of varying composition.

The density of clays may, however, be increased by pressure.

Estimation of Components.

Without entering on exhaustive analysis, a potter often needs to know whether certain ingredients are present, and their approximate proportion; a few tests suitable for these purposes are here described.

Iron.—The presence of iron may easily be discovered as follows:—Take a small quantity of the clay. Powder it finely. Add sulphuric acid diluted with three times its volume of water. Let the mixture stand for a day, then dilute with water. Filter off the liquid, and heat this with a piece or two of pure zinc. Next add a small quantity of potassium permanganate. By this means all the iron present may be thrown down in a precipitate.

Lime.—If present in the form of carbonate, a small quantity of acid poured on the clay will cause effervescence, due to the liberation of carbon dioxide.

Water.—This is the simplest estimation, consisting only of the heating of a weighed quantity of the powdered clay. The temperature must reach 120° C., and be maintained until the total residue shows no diminution in weight. The loss represents the amount of moisture present. If the residue now be heated up to a temperature not exceeding 700° C., a further reduction in weight will occur. This represents the loss of combined water of the hydrosilicate of alumina (which contains 13·90 per cent.), and of the organic matter present.

Estimation of Texture.

This is perhaps the most difficult of all tests of clay material. It is true that, to some extent, microscopic examination affords an indication; but the measurement of the relative size of the particles and the separation of the same cannot be practically accomplished on this plan.

The use of levigation has also been resorted to. The clay is put into a vessel, and into this water is constantly allowed to run from a height, at a speed sufficient to remove all but the largest particles.

The overflowing liquid, carrying the lighter particles with it, falls into a second vessel so arranged that the current is diminished, thus allowing a settlement of the heavier particles therein (Fig. 1).

In the same way the liquid overflows from the second vessel into a third, where, by retarding the current, the still finer particles are deposited.

The residue in each vessel is dried and weighed. From these results the proportion of various sized grains may be obtained.

To obtain accurate data, considerable precision is required, and the clay should first be sifted through a coarse sieve, to prevent the apparatus from becoming choked.

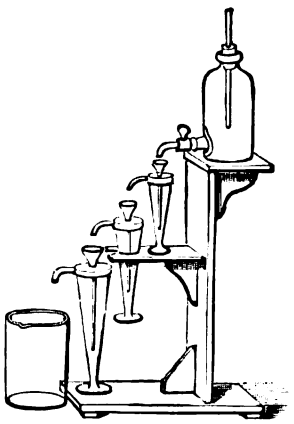

Fig. 1.

The smoothness of texture or "fatness" of a clay material may be approximately compared by the method suggested by Bischof, who recommends mixing a known weight of the powdered clay with increasing proportions of fine sand. Water is added sufficient to bring the mixtures to the plastic state. Each is then dried. The texture is compared by the amount of disintegration which can be caused by rubbing the dry mass with the ball of the thumb. The proportion of sand, contained in that mixture which yields only very slightly to rubbing, is taken as the indication of the texture.

The presence of other ingredients naturally alters the texture of the clay mass, because all substances other than clay are relatively far coarser in grain, even to several hundredfold.

Hydrates of silica, alumina, ferric oxide, and fine mica give the finest grain, while calcium and magnesium carbonates produce intermediate results, quartz and felspar being still larger.

The quality of texture in clay materials plays a very important part in pottery manipulation, and on its careful adjustment the success of manufacture often depends. It greatly influences the working properties when in the plastic state, and also the speed at which the process of drying can safely proceed. Beyond this, the amount of shrinkage and warping is more or less affected by the texture of the body.

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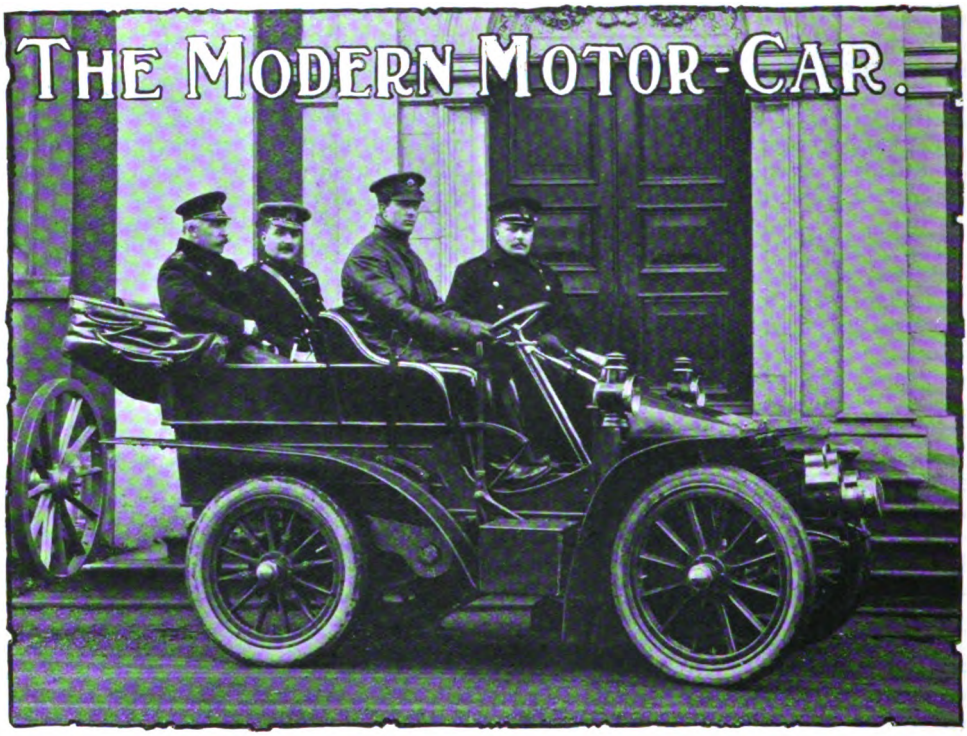
THE MODERN MOTOR-CAR.



By WILFRID J. LINEHAM, M.I.C.E., M.I.M.E., M.I.E.E.

In Parts I. and II., the explanation of the driving mechanism of a modern car was completed. The present and concluding part will, therefore, concern itself with the remainder of the *chassis*, with some reference to prominent types of car other than the one chosen.

Part III.

The Front Axle and the Steering.

The portion of the front axle (Fig. 33) that is fixed to the frame and springs is of rigid construction; but outside these limits the axle has two joints or forks, one on each side, from which are carried the projecting arms that constitute the wheel journals. These arms are again connected by two levers and a coupling rod, the levers being splayed outward when the coupling rod is in front, but inward when the rod is at the back of the axle; and the steering rod is connected to a third lever fixed to one of the joints. When the steering rod is pulled from the steering pillar, the wheels are made to deviate, but not to equal amounts in both cases: thus a left turn being indicated in the diagram, it is seen that the left-hand wheel has the greater deviation. In short, the coupling rod is made of just such a length that, however much the wheels are turned, their centre lines will meet upon the centre line of the hind axle produced as in Fig. 34; this meeting-point

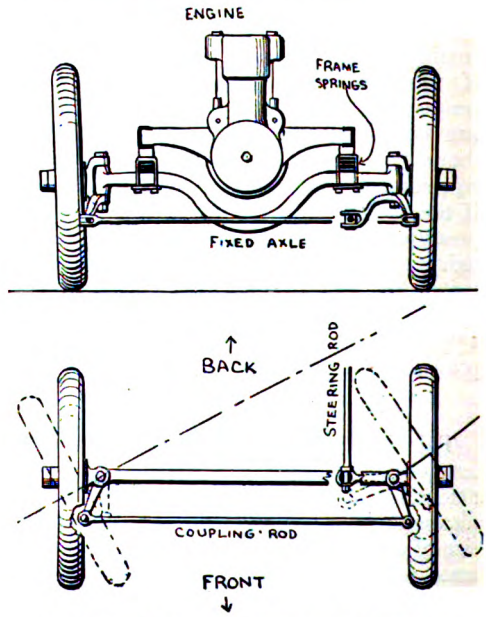


Fig. 33.—The "Ackermann" Steering Gear.

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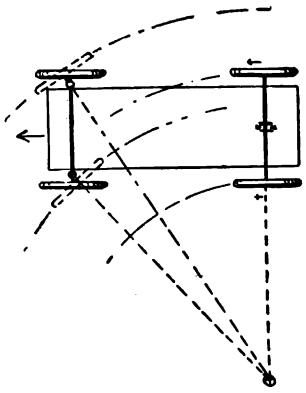

FIG. 34.—GEOMETRY OF ACKERMANN GEAR.

determining the centre round which the car will rotate upon the ground.

As to the steering handle itself, the wheel has all but entirely displaced the earlier tiller form, because the latter could with difficulty be made self-holding, and it was difficult to turn one's head for a moment when directing the tiller without upsetting the car. The hand wheel A (Fig. 35), actuating a worm gear B, and a lever C connected to the steering rod, is an easily-worked contrivance, which will hold the front wheels without over-attention, and so, as I said, has become practically universal. Various small levers are seen at D, which scarcely need careful description; suffice it to say that they are merely required for a number of adjustments of the car mechanism, such as "advance spark," adjusting of the mixture or "carburation," etc.

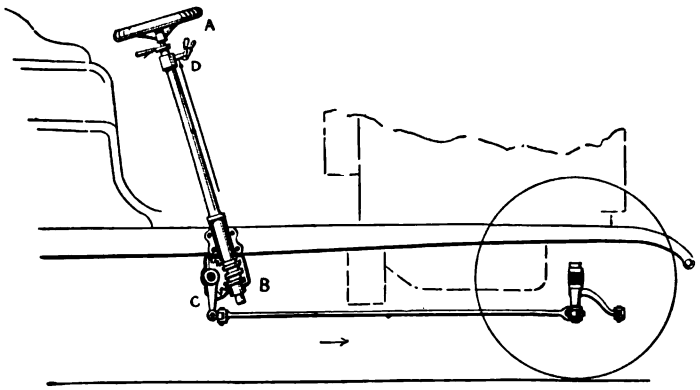

FIG. 35.—THE STEERING PILLAR.

THE BRAKES.

The law requires two sets of brakes—without doubt a perfectly rational demand; and these are provided for in the modern car, by placing one brake drum on the propeller shaft (or alternatively on the chain shaft), and one drum on each hind wheel. The former is generally put immediately behind the gear box, and may be called the shaft brake. It is more commonly used for slight changes on an approximately level road, while the second or hind wheel brake is jammed on pretty tightly for the purpose of descending steep hills: both arrangements are shown in the general view, Fig. 36. As to the actual construction, the strap brakes formerly adopted are being largely abandoned in favour of some form of expanding or contracting blocks, for the reason that the strap brake will not "reverse," that is, will not prevent a car backing down hill; and a sprag has then to be applied, which is awkward and unmechanical. Rigid blocks, however, will act well either on the forward or backward rotation.

The shaft brake is shown in Fig. 37, worked by a foot lever. It consists of a metal drum encircled by two clamping levers, which are provided with renewable cast iron shoes: these latter are pulled nearer to each other at their upper ends by the action of the foot rod, the abutment being obtained by a bracket on the frame. The main brakes on the hind wheels may be of similar construction, and are so represented in Fig. 38, with the simple exception that the two blocks are forced apart instead of being pulled together. To put the brake in action, a toggle lever A is pulled over by the steel cord connected to the hand lever: the upper hinge pin is supported by a bracket B which is held firmly to the frame by the rod C. Some makers still adopt strap brakes on the hind wheel, as in Fig. 39, which are of course only used when travelling down hill: the shaft brake must then be used to prevent backing.

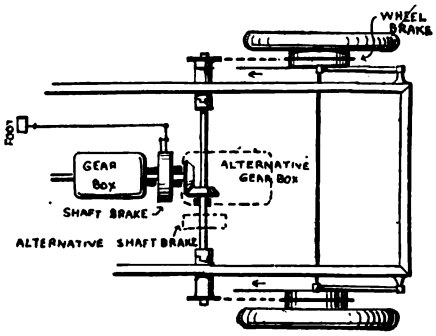

FIG. 36.—ARRANGEMENT OF BRAKES.

Now in order that the brake pull may be

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applied to both wheels at once, the hand lever A (Fig. 39) must be fixed to a shaft lying across the frame, and the brake rods or cords be connected to short levers also keyed thereon. There is still the risk that the pull on the wheels may not be uniform, and some compensating device becomes a necessity. The Panhard steel cord (Fig. 40) passing through a hollow brake shaft has been extensively adopted, but it can scarcely be considered an admirable arrangement. Various forms of levers have been substituted by other firms, the "Argyll" construction, Fig. 39, being very noticeable. Here the brake levers BB act upon the fulcra of bell-crank levers CC that connect to the brake rods, the pull being resisted by the coupling-rod D, which is adjustable in length. These levers, turning freely on their fulcra, make the three rods into the equivalent of the Panhard rope; but the arrangement is much more sensitive and effective. Other methods have been used, but these two will serve as typical cases.

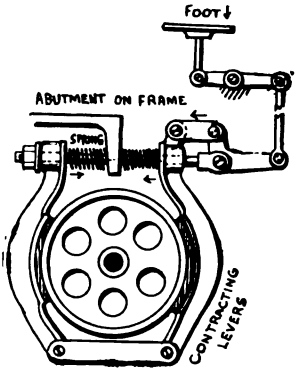

FIG. 37.—THE "ALBION" PROPELLER-SHAFT BRAKE.

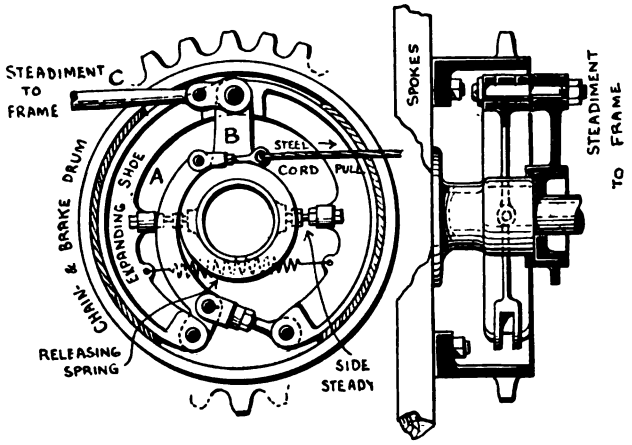

FIG. 38.—THE "CROSSLEY" WHEEL BRAKE.

And now I have all but completed the promise with which I set out: to describe the modern motor car and its mechanism from an engineer's point of view. The reader has been carried over the car from the engine, with all its charming adjustments, automatic or otherwise, the change speed gear, the slipping clutch, the drive to live axle or chain, to the steering gear, and the brakes. A few more words of a general character may, I think, be advantageously added; and firstly, as to distribution of weight. A good-sized car will weigh (empty) somewhere about 17 or 19 cwts., say 2,000 lbs.; and the load of four people with some luggage may represent 800 lbs. This is a great advance in carrying power over the early practice referred to by Sir David Salomons. I should like to see some of our standard motor cars weighed as to the load on each pair of wheels, rather than to take the car as a whole: I do not remember an account of anything of this kind being published. Old locomotive practice was very decided in requiring to have the lighter weight in front, the heavier behind, and the heaviest on the driving or mid-wheels. An examination of the most usual car would, I think, show either an equable distribution, or perhaps even a preponderance upon the front wheels, which would give what we call heavy steering; and a readjustment of these matters may be looked for in the future, especially in view of the very bad side skidding on the steering wheels that often takes place. All that is possible has already been done with the build of car I have explained; *viz.*, as the engine has been put in front, so as to admit the rest of the mechanism conveniently, the water-tank, silencer, live load, and luggage have all been placed behind. The petrol tank is usually put in front of the dash-board, being between the latter and the engine cylinders. It is not too safe a place, but is convenient, and no complaints have been heard up to the present time.

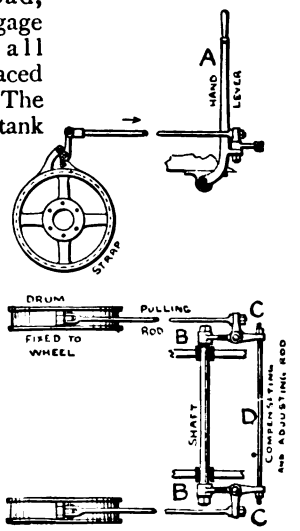

FIG. 39.—THE "ARGYLL" WHEEL BRAKES.

OTHER CARS.

Having set out to describe

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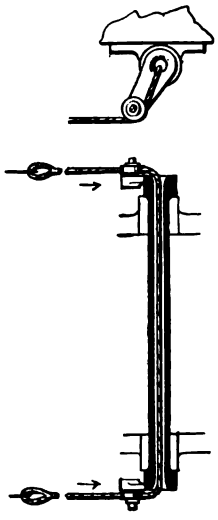

FIG. 40.—THE "PANHARD" BRAKE COMPENSATION.

the modern motor car, I had perforce to choose the most typical form, or that which is being manufactured by the largest number of firms. The reader must be warned, however, against imagining that this design has become fixed and unalterable; far from it, for many cases of completely different arrangement of parts have succeeded and are succeeding most excellently. To some of these I shall now draw attention. The Duryea Car, Fig. 41, has three horizontal engines arranged longitudinally, and runs with almost no vibration, for reasons already mentioned. The engine-shaft being placed transversely, is coupled by chains to a live axle, two sets of epicyclic change-gear being interposed to give three speeds and reverse. The Wolseley car has also achieved great renown, very largely due to the excellent manufacture of its parts, and the arrangement is somewhat similar to that of the Duryea, *viz.*, horizontal cylinders and direct chain drive.

I think the most interesting car at the shows, speaking technically, was undoubtedly the "Lanchester." Mr. Lanchester is well known to students of the gas-engine, and everyone expects valuable ideas from him. In his car, he adopts two cylinders with opposed pistons (Fig. 42), and places balance weights on the two gear-connected crank-shafts, in such wise as to completely annul the inertia of the cranks, connecting rods, and a portion of that of the pistons; the remainder of the inertia of the pistons being neutralised by their opposed motions, and a completely-balanced engine results, both as regards masses and explosions, the only objection being the short rods, which make very abrupt angles in their extreme positions. If space permitted I should dearly like to describe all the interesting novelties on this car, but this would require a long article in itself. The following claims may be mentioned:—

1. A completely-balanced engine.
2. Efficient *air*-cooling of cylinders through a jacket.
3. Quiet worm drive on to back axle.
4. Automatic lubrication.

Another balanced engine of very great interest is the "Gobron-Brillié," which I have shown in section in Fig. 43. Here the cylinders are closed at both ends by pistons only, those nearest the crank being connected thereto by the usual inside connecting rods, while the further ones have short rods inside to a transom or gudgeon, and long rods outside to cranks which directly oppose the others. The explosions moving the pistons simultaneously outward, the reciprocating weights in one direction are made to completely balance those moving oppositely, and there are no explosions to balance; in fact, there is little doubt that the construction ought to be more generally adopted. The engines are put up in pairs as shown; but, if they were made singly, one set might be arranged at 90° to the other, with the result of a more even turning effect, a matter which I should think desirable. The single set could also be used upon a smaller-sized car.

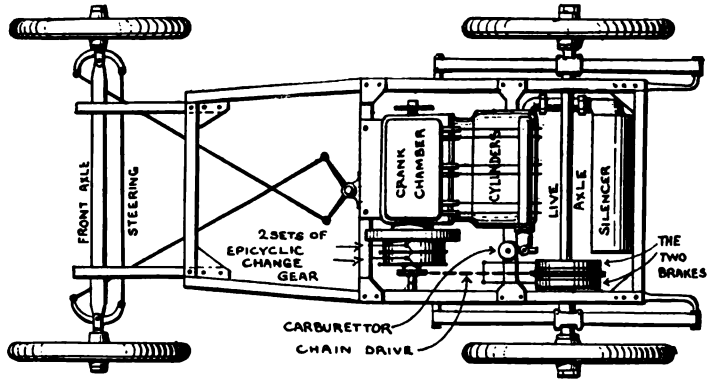

FIG. 41.—THE 10-H.P. "DURYEA" CAR.

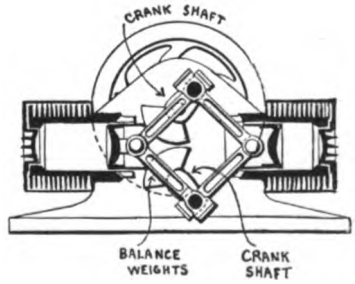

FIG. 42.—THE LANCHESTER TWO-CYLINDER BALANCED ENGINE.

EPICYCLIC GEAR.

I must not forget the Wilson-Pilcher car, now con-

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structed by Armstrong, Whitworth and Co. This car probably received more attention than any other at the Crystal Palace Show, with the exception of the Lanchester; not only on account of its mechanical interest, but because no car could beat it for silence and lack of vibration, as I proved to my own satisfaction by actual trial. Fig. 44 will serve to show the arrangement of the car. There are four or six cylinders in front, lying across the frame and having moving parts balanced. The engines are further supported by being slung bodily from a bracket above them, and by steadiment to the frame with strong spiral springs. The fly-wheel is in front: A is the main friction clutch, while B and C are epicyclic gear-boxes, from which the power is transmitted to the live axle. The forward or reverse motion, as may be required, is effected by moving the wheels D and E (as one block) along the hind axle, by means of the lever H, so as to gear respectively with the pinion F; and the compensating gear is contained in the box G. To understand the change gear, consider Fig. 45, where a hollow or "annular" spur wheel A is supposed to be fixed to the paper, while a second, loose, wheel L is connected thereto through an intermediate pinion mounted on an arm. When the arm has been rotated through a circle, the wheel L will have partaken of two motions: one due to the arm, and the other to its connection with A depending on the ratio of the wheels A and L, so that when the arm has rotated once the wheel L will have revolved $\left(1 + \frac{A}{L}\right)$ times. If the diameter of A be twice that of L, the revolutions of L will be three times that of the arm. In practice, imagine that L is the engine shaft, and the propeller shaft is coupled rigidly to the arm. Then the speed would be reduced on the propeller shaft to one-third of that of the engine shaft, taking the proportions we have supposed; and, of course, other ratios can be provided by altering the size of L. Further, if A be freed and the arm connected rigidly to L, the whole rotates solidly, and provides another speed of shaft by a direct drive—Fig. 46 will illustrate the practical means, two friction clutches being there provided, one to fix A to the frame, and the other to fix L to the engine shaft, each when required. A is the annular wheel, B the "arm" carrying the intermediate, and L the central wheel. If A be fixed to the frame by bodily movement to the right with a clutch lever, the rotation of engine shaft L causes B to rotate at a reduced

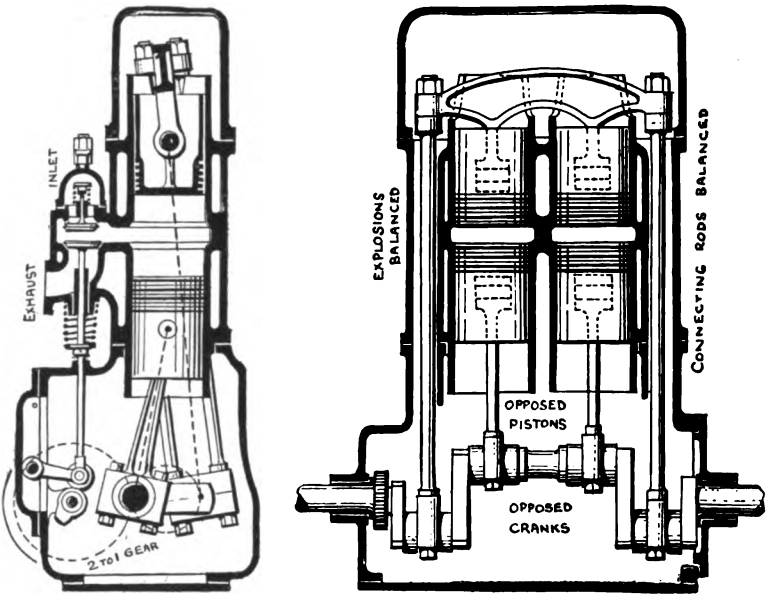

FIG. 43.—THE "GOBRON-BRILLIÉ" BALANCED ENGINE.

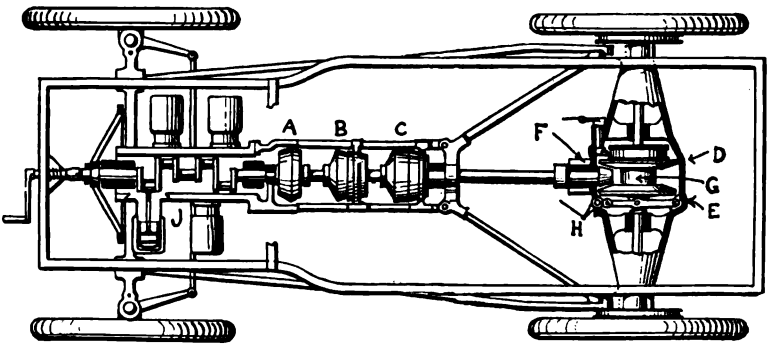

FIG. 44.—THE WILSON-PILCHER CAR.

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FIG. 45.—THE EPICYCLIC PRINCIPLE.

speed; but if A be moved to the left it is thereby fixed to the engine shaft and a direct drive obtained. Two such boxes are provided, and by their combination four forward speeds are produced, as will be seen diagrammatically in Fig. 47; fourth speed is a solid drive: third speed requires first box free and second solid: second speed has second box free and first solid; and at first speed both boxes reduce simultaneously. The epicyclic arrangement of gear has much to recommend it, and has been adopted in the Lanchester, Duryea, Oldsmobile, Albany and other cars. It is non-jerking on changing, for the teeth are always in mesh and yet are not in action except when reducing; nor does it occupy great space.

FRAMES AND TYRES.

One word on frames. Up to the present these have been built up in lengths of channel-sectioned steel bar, stiffened or not with wood; and wherever cars are manufactured in small quantities there seems no other way. The engine and gear box were formerly carried on a second and narrower frame, but this is now rarely done, the castings being extended instead till they reach the main frame. Not the least interesting advance of this year was shown by the Darracq firm, whose car frame was entirely stamped out of one sheet of steel $\frac{1}{8}$ in. thick, turned over at the edges to form a channel section. The plate was also carried inward as a support for engine and gear box, thus reducing the weight of the latter. There is no doubt that such an important advance is not only economical of material, but gives increased stiffness; and I have therefore tried to indicate the general form in Fig. 48. There are yet other advantages connected with the construction, such as the shielding of the mechanism from dust.

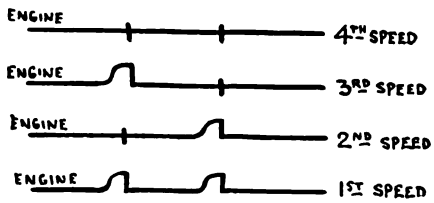
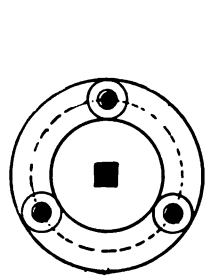


FIG. 47.—FOUR SPEEDS WITH TWO EPICYCLICS.

Pneumatic tyres are well known. The high pressure to which they are subjected when highly pumped (100 lbs. per square inch), together with the liability to side-slip, are serious defects, and tyre troubles are rarely absent on a tour. There has recently been a very decided movement in favour of "solids," which are said to be fairly resilient when the car speed keeps within 20 miles per hour. Jackson's spring wheel is guaranteed by its makers to give satisfactory resilience; and although it goes against our preconceived notions, it should not be condemned untried. Two forms are manufactured. In one the springs are near the hub, Fig. 50, and in the other just within the rim, Fig. 49: they are always in compression. The first form Jackson's themselves prefer, because, they say, the



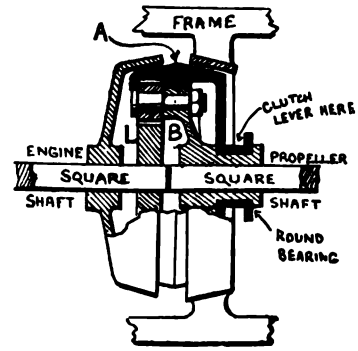


FIG. 46.—EPICYCLIC REDUCTION.

wheels keep well down to the road, and the frame alone rises and falls. The second form of spring wheel, I was told, more nearly imitates the characteristic bounce of the pneumatic tyre, as would be expected. I hope to myself try this spring wheel shortly; practical trial is the only real proof.

THE PRICE OF CARS.

It is pretty clear, after reading these articles and viewing the diagrams, that a motor car is none too simple a contrivance, and can never be produced at an excessively low price. When the motor manufacturer has spent a little longer time catering for the pleasure tourist, I trust he will be able to turn his attention to the "runabout" man, who, obtaining a due return for his money in facility of transit and saving of railway fares, may be induced to appear in his tens and hundreds of thousands as a car purchaser. Some cars of this character were shown at the Crystal Palace in February, one really excellent example at 100 guineas, and another at 70 guineas; but the single-cylinder

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engine was the great objection to them, in my mind. When car design shall have settled down still further, and be in the hands of great manufacturers who have arranged for excessively cheap repetition by machine tools, I fully believe a £100 car (not 100 guineas) will be produced that shall have a two-cylinder engine perfectly balanced, and otherwise be all but vibrationless and silent. *We all want that car badly*, and the first manufacturer who can supply it will deservedly secure a large market.

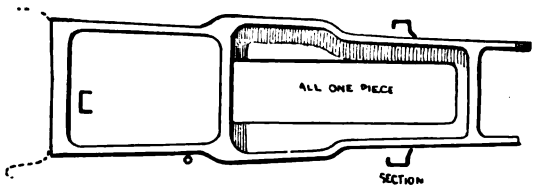

FIG. 48.—THE "DARRACQ" PRESSED STEEL FRAME.

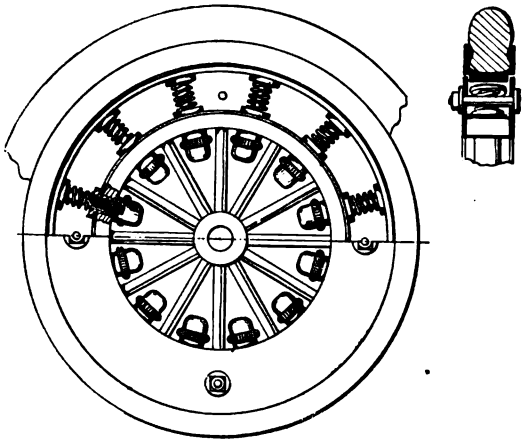

FIG. 49.—THE JACKSON SPRING WHEEL.

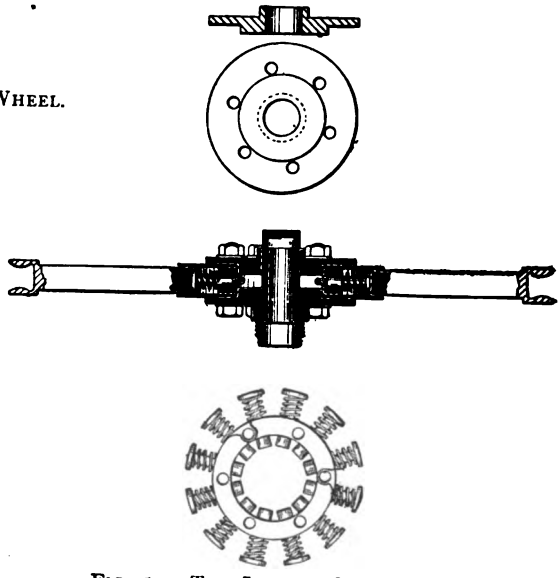

FIG. 50.—THE JACKSON SPRING HUB.

(We are indebted to the Wolseley Tool and Motor Car Co. for the photograph from which the head-piece for this article has been reproduced.)

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THE FIBROUS CONSTITUENTS OF PAPER.

No. II.—Cotton.

By CLAYTON BEADLE, F.C.S., F.R.M.S.

Illustrated with Photo-micrographs by John Christie, F.R.M.S.

COTTON may be regarded as the *alpha* and *omega* of paper-making fibres. In all probability, cotton was the first material used for the manufacture of paper. Its first use for this purpose is buried in obscurity. Joseph Amra is credited with being the first to have manufactured cotton paper in the year 706, but manuscripts on cotton paper —some in good preservation—are found to date back to much earlier periods. The use of cotton paper in Great Britain certainly dates back to the eleventh century; and no other material seems to have been used until about the middle of the fourteenth century, when linen became available for the purpose of paper-making.

Cotton may be regarded as the *omega* of paper-making materials, in the sense that it bids fair to outlive all existing materials—not as to quantity, but durability. It consists of the purest and least destructible kind of cellulose, and it has stood the test of time better than all other paper-making materials. Manuscripts on cotton paper more than a thousand years old are still extant; whereas much modern literature on "mechanical" wood goes to pieces in the course of a few years, or on exposure to bright sunlight even in a few days.

Cotton belongs to the genus *Gossypium*, order *malvaceae*. It is a seed-hair consisting of ultimate fibres. It varies in length from 2 to 4 cm. or from 1 to 2 inches, and has a diameter varying between 0·012–0·037 mm.

We need only consider the characteristics and general behaviour of the cotton fibre, in so far as relates to the manufacture of paper. There is considerable difference between the various stages of growth, not only in general structure, but in behaviour towards chemical treatment; as well as in regard to the character of paper produced. There are three stages of growth or development, *viz.*, the ripe, half-ripe, and unripe fibres. Practically the only source of cotton to the paper-maker is cotton rags. Only such fibres, therefore, as are available for the purpose of spinning and weaving, find their way into the hands of the paper-maker. These are mostly the fully-developed fibres. The unripe fibres, which remain attached to the husk of the cotton-seed, will undoubtedly be available for the manufacture of paper so soon as a process is devised, either mechanical or chemical, for their separation from the husk.

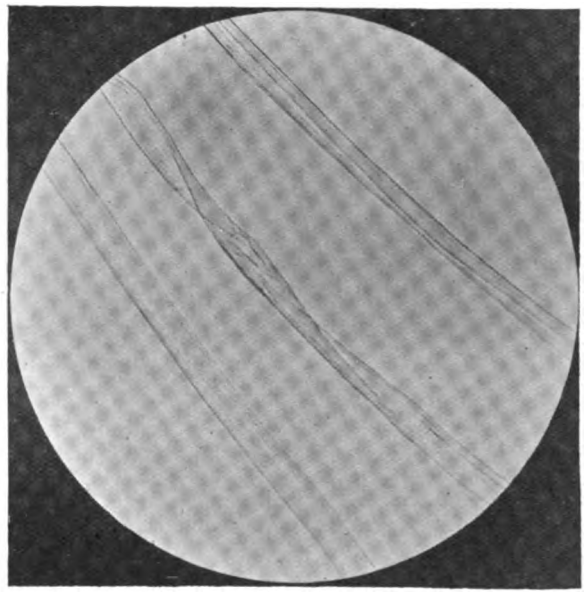

Fig. 1.—Cotton Fibres, Straight, Twisted, and Collapsed.

(*Magnified 225 diameters.*)

The fully developed cotton fibre has the general appearance of a collapsed tube, with a fairly thick wall. For lectures purposes, an excellent demonstration of the structure of the cotton fibre can be arranged by taking a long piece of rubber tubing, clamped at one end and exhausted of air so as to cause the walls to collapse, and then closed at the

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other end. On letting go the ends, it will be found that the collapsed tube twists on itself like a corkscrew, as the result of irregularities in the thickness of the wall. Exactly the same thing happens with the cotton fibre: it collapses on itself in the course of growth and development, and has anywhere from 15 to 300 twists in the length of the single fibre (Figs. 1 and 2).

The special paper-making characteristics of cotton are largely to be accounted for when regard is had to the peculiar contour of the section, as well as to the spiral twistings of the fibre (Figs. 1, 2, and 8). It consists chemically of pure cellulose (C_6 H_{10} O_5) in its most inert form. The natural fibre contains about 0·5 per cent. of waxy bodies, 0·5 per cent. of nitrogenous substances, and 7 per cent. of moisture. The surface or cuticle of the fibre is more resistant than the granular cellulose constituting the interior. The cuticular cellulose constitutes about 10 per cent. of the weight, and the remaining 90 per cent. is known as the intercuticular cellulose. This distinction is of very great moment to the paper-maker, perhaps without his knowing it; the general behaviour of cotton, when mechanically treated, depends largely on the extent of the removal of the cuticular cellulose. Old and new rags behave very differently in this respect.

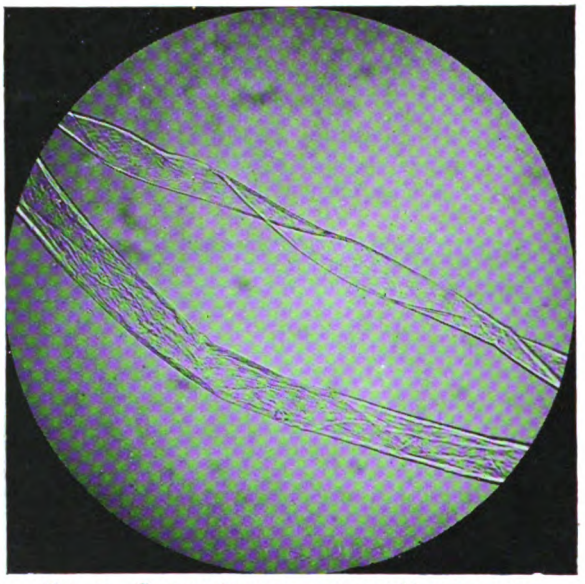

FIG. 2.—COTTON FIBRES, SHOWING MARKINGS ON SURFACE.
(*Magnified 225 diameters.*)

Cotton rags used in the manufacture of paper are received by the paper-maker in bales or bags weighing from 1 to 5 cwts. These are "shot" in the rag house, and submitted to preliminary treatment for the removal of loose dirt, by passing them through a revolving cylinder covered with coarse wire gauze. For the very highest quality of paper, the dusted rags are hand-cut at the "hurdles," and sorted into different qualities by hand. But where so much care has not to be exercised, the rags are sorted by hand, and machine cut into strips from two to four inches square. They are then fed into a "willow," consisting of two drums revolving at different speeds in an enclosed box, both the drums and the sides of the box being provided with prongs. The rapid beating motion of the willow detaches a large amount of dirt, which is easily separated when the rags are passed through a revolving "duster." The dust is found to contain 10, 20, 30, or 40 per cent. of ash, depending upon the stage of separation; and also anywhere up to 12 per cent. of nitrogenous matter. The proportion of dust may amount to 5 per cent. on the weight of the rags, but varies with each individual quality, as well as with the extent of the mechanical treatment. The dust is useful as a fertiliser for plants. There is a large proportion of fibres in the dust which unavoidably become mechanically separated from the fabric during the dusting.

Cotton rags are boiled either in a solution containing milk of lime or caustic soda. In the former case, insoluble lime salts are formed by the action of the lime upon the resinous and fatty bodies with which the fibre is associated. These insoluble lime compounds are mechanically removed, either during the boiling, or in the washing which follows. When caustic soda is used, soluble soda compounds are formed, which are mostly contained in the boiling liquor, and are easily removed by washing.

The types of boilers used are either horizontal, cylindrical, or spherical: they are made to revolve very slowly, so as to promote even circulation through the mass. It has been found, after extensive trials, that no advantage is to be gained by using a higher

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steam pressure than about 20 lbs. to the square inch. High pressures are frequently disadvantageous, resulting in boiled rags of a lower colour than at the more moderate pressure. Sometimes "kiers" are used for cotton rags, the liquor being made to circulate through the mass by the aid of a centrifugal pump. Here we need only consider the case of revolving boilers at a pressure of 20 lbs. to the square inch.

The following is a practical and rapid procedure for arriving at the best condition for boiling rags with soda, which can be carried out by any ordinary works chemist. One quality of rag is taken for investigation. The rags are filled into the boiler with a known quantity of soda. The capacity of boiler, the weight of rags, and the volume of liquor are noted. The charge should be as much as the boiler will take when "trodden in," after the liquor is added. The liquor should be just sufficient to ensure complete saturation of rags, but no more. The time of bringing the boiler to full pressure is noted. Samples of liquor are withdrawn every hour and tested for "free" soda, and the boiling is continued until the free soda remains practically constant.

The total soda is determined in the first and last sample; in the case of a boiler heated with a steam coil, the total soda should remain constant throughout the boiling. When the rags are washed and removed from the boiler, a sample is kept for comparison.

A second boiling is conducted on the same lines, but using soda very slightly in excess of that found to be consumed or neutralised in the first trial; the result should be practically the same. In order to ascertain the loss during treatment, 10 lbs. of rags, which must be so selected as to be representative of the bulk, are tied up in a loose bag made of coarse cheese-cloth. This bag is reclaimed after the boiling, and the contents, after washing, are exposed to the air to air-dry, and weighed. From this the loss during boiling is calculated.

Description of Rags.	Boiled Rags, Yield of Air-dry, per Cent.	Loss on Boiling, per Cent.
Best new cotton pieces	91·29	8·71
Low ,, ,, ,,	87·8	12·2
Cotton rags, No. 1	94·2	5·8
,, ,, ,, 2	93·0	7·0
,, ,, ,, 3	87·5	12·5
,, ,, ,, 4	86·7	13·3
New unbleached cotton	76·5	23·5

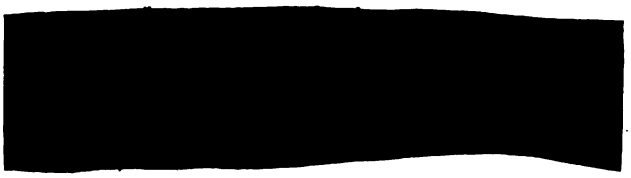

Photo-micrograph by] [*H. de Mosenthal.*

FIG. 3.—COTTON FIBRE, SHOWING SPIRAL ROWS OF STOMATA.

(*Magnified 1,000 diameters.*)

The preceding table gives the yield and loss on boiling various grades of cotton rags, determined by the method above indicated.

The examination of liquors taken during the boiling, to avoid unnecessary calculation and work, are treated as follows:—The liquor for each hour is placed in a marked bottle. The bottles are fitted into rough wooden boxes, which can easily be transported. Each box contains a series of bottles sufficient for a boiling. By this means samples from half-a-dozen boilings can be transported from boiler-house to laboratory by the chemist. From each sample 32ccs. are withdrawn by means of a pipette. This is titrated with normal sulphuric acid, until it no longer shows alkalinity when a drop is placed on a perfectly neutral, non-absorbent litmus paper. On account of the deep colour of the liquor, no indicator can be used in solution. For determination of total soda, 32ccs. are evaporated down in platinum dish, ignited, and the charred

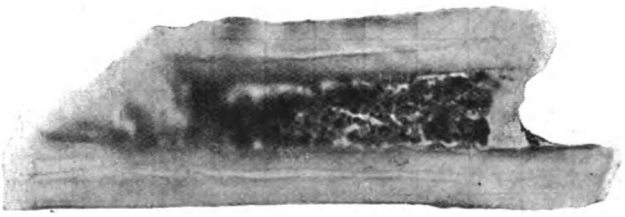

Photo-micrograph by] [*H. de Mosenthal.*

FIG. 4.—LONGITUDINAL SECTION OF COTTON FIBRE, SHOWING OUTER AND INNER CUTICULAR LAYERS, AND INTERCUTICULAR SUBSTANCE.

(*Magnified 1,000 diameters.*)

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mass wetted with water and again ignited. The soda can then be dissolved out with water, and titrated without filtration. The readings on burette give the percentage of Na_2O by dividing by ten. This method of determining the free and total soda has been checked by evaporating a quantity of the liquor to a solid mass, and examining for "free" soda by the method of "salting out." The two methods give sufficiently concordant results.

Dilute liquor tested as above, 28·5 per cent. of "free" on "total" soda.

Concentrated and "salted out," 26·9 per cent. of "free" on total soda.

When once the conditions of boiling are fully established, check tests can be carried out from time to time in a more simple manner. Portions of the first and last samples are mixed in equal volumes, from which 32ccs. are withdrawn, and total soda determined. A quantity of each sample is then measured off such as to give reading on burette, which when divided by ten, represents percentage of "free" on "total" soda without further calculation. The results are finally expressed in percentage of "free" soda on "total" soda. By examination of these figures, the exact behaviour during boiling can be ascertained. I have found, moreover, that still further can be learned by plotting curves, showing the diminution of "free" soda per hour during boiling, expressed in percentage on "total" soda per cent.

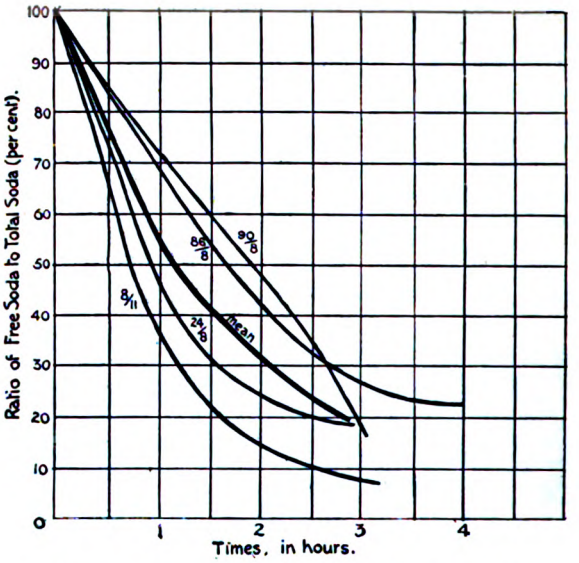

Fig. 5.—Curves, showing Exhaustion of Soda in Boiling Different Cottons.

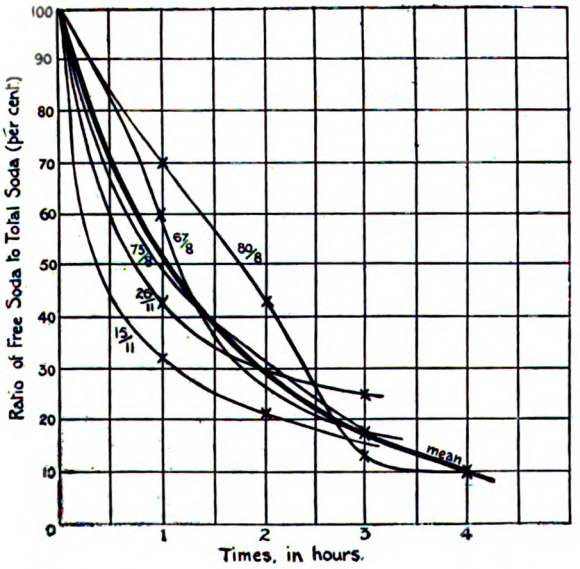

Fig. 6.—Curves, showing Exhaustion of Soda, with Third Quality Cotton Rags, under varied conditions of treatment.

The table on page 571 shows the conditions arrived at after pursuing the mode of procedure above indicated. It must be remembered that no two mills have the same requirements, and there is no regular plan of procedure common to them all, or to the majority of them. Furthermore, the different grades of rags in one mill are not comparable with those in another. The table, therefore, cannot be used as a guide for general practice, but merely as showing the mode of expressing the different factors of boiling; and by comparing these with curves constructed as above indicated, an idea can be arrived at as to how the conditions influence the rate of absorption of soda.

Fig. 5 shows the absorption of soda per hour by different qualities of rags when treated under the conditions shown in table.

Fig. 6 shows the absorption of soda per hour by third quality cottons when the conditions are varied, as

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Reference.	Quality of Rag under Treatment.	Weight of Charge in Cwts.	Gallons of Liquor added per Cwt.	Strength of Cold Liquor Na_2O per Cent.	Percentage of Na_2O on Rag.	Percentage Free Na_2O in Solution at Different Stages of Boiling.						Free Na_2O at Different Stages of Boiling, when Total Na_2O = 100.					
						0 hour.	1 hour.	2 hours.	3 hours.	4 hours.	5 hours.	0 hour.	1 hour.	2 hours.	3 hours.	4 hours.	5 hours.
90/8	No. 1 Cotton / No. 2 ,, mixed	—	—	—	—	·215	·155	·102	·038	—	—	100	72	48	18	—	—
8/11	,, ,, ,,	32	24	·33	·697	·22	·083	033	·017	—	—	100	38	15	8	—	—
24/8	No. 2 Cotton	—	25·7	·654	1·68	·54	·26	13	·10	—	—	100	48	24	19	—	—
67/8	No. 3 Cotton	—	22	·90	1·78	·60	35	·16	·10	—	—	100	60	27	17	—	—
73/8	,, ,,	—	24	·70	1 50	50	245	·155	·085	—	—	100	49	31	17	—	—
80/8	,, ,,	—	25·2	·55	1·22	35	·245	·152	·068	·036	—	100	70	43	13	10	—
15/11	,, ,,	31	24	·65	1·36	·42	·13	·09	·065	—	—	100	31	21	15	—	—
26/11	,, ,,	30	25·5	·76	1·74	·60	·255	·180	·150	—	—	100	43	30	25	—	—
86/8	No. 3 Cotton / No. 4 ,, mixed	—	25	·80	1·74	·50	·345	·215	·13	115	—	100	69	43	26	23	—

shown in the table. The curve, constructed as the mean of this latter series, is extremely regular, and gives a good idea as to how the rate of absorption of free soda should progress in favourable circumstances. Broad conclusions can be arrived at from a mean of all the curves, which should hold good, in a measure, for all classes of rag boiling. About one-half the total soda is neutralised at the end of the first hour, and after the third or fourth hour the chemical treatment has practically come to an end. Further treatment is not only wasteful and unnecessary, but harmful, as the rags go bad in colour. Many paper-makers, however, are treating from twelve to twenty hours, as they have no means of telling when the action is at an end. The amount of soda used is often merely a matter of guesswork. Some such system as I have outlined above should, I venture to think, be introduced into every paper mill where rag treatment on an extensive scale is carried on.

New cotton rags frequently contain a quantity of starch and loading which may vary between 5% and 50% of their weight. Starch is acted upon in a very curious manner by the dark boiling liquors. These liquors frequently contain pectose substances and bodies of a similar nature. The joint action of these with the soda produce a dark insoluble cheese-like substance, consisting of starch and organic bodies. The new rags, instead of being white after this treatment, are frequently dark in colour and covered with a slime. To overcome these difficulties the author recommends a process which he introduced some years ago, whereby the starchy rags are acted upon by a solution of malt extract at a temperature of about 170° Fahr., resulting in the starch being converted into sugar. If it should be found necessary, after this treatment, to boil in plain water, or water containing soda, no difficulty arises, the starch being completely removed.

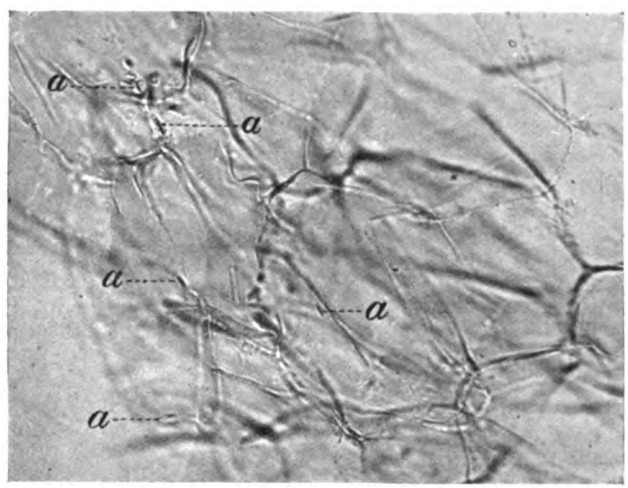

Photo-micrograph by] [*H. de Mosenthal.*

FIG. 7.—CUTICLE OF COTTON FIBRE, FROM SOLUTION OF CUPRAMMONIUM. THE STOMATA ARE SEEN AT *a*, *a* . . .

The rags are submitted to a preliminary wash in the boiler itself, after which they are discharged from the boiler by the removal of the man-hole, and allowing the boiler to rotate. The boiled rags are received in a pan below, with a perforated bottom, where they drain.

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Where cleanliness is of very great importance, as it generally is in a rag mill, the rags are submitted to a wash in an oblong trough with false sides and bottom of coarse wire. The trough is kept nearly full of water, and revolving propellers are made to agitate the floating rags, and convey them from one end of the trough to the other; during which process a great deal of dirt is dislodged which finds its way through the meshes of the wire gauze. A great deal of fibre, however, passes away with the dirt during this treatment, and can be caught on screens, and in the form of "lint" is available for low-class papers.

The old method of "tumbler" bleaching, in which the rags were bleached before disintegration, is practically abandoned. The general practice now is to place the rags in the "breaker," where they are reduced to the condition of "half-stuff," and at the same time washed free from dirt by a continuous current of fresh water which mingles with the stuff in front of the roll, and is taken off through a revolving drum covered with wire gauze and provided with a syphon or lifting buckets. The wash water contains a large amount of dirt in suspension originally associated with the fibre. If the washing is so prolonged as to remove a very large proportion of mechanical dirt, there is danger of a considerable amount of fine fibre also escaping through the wire meshes of the washing drum. The makers of high-class writing papers find it expedient to carry the washing so far as possible, as freedom from dirt is of primary importance in high-class papers. The fibres in the wash water can, in a larger measure, be reclaimed by allowing the water to flow into the interior of a long revolving drum, covered with fine wire gauze and inclined at a slight angle. The water passes through, and the fibre, mixed with some dirt, gathers up into balls and discharges itself at the lower end of the revolving drum. Or the wash water may be treated by passing it through filter presses, or an arrangement for settling out the fibres, such as the Fulner separator. The fibre so reclaimed is known as "save-all": it is short and dirty, and can be used only on low-class papers.

The washed half-stuff in the breaker is frequently emptied into a potcher, which is a machine for mixing it with the bleach liquor. Bleach equal to from 2% to 5% of bleaching powder on the dry weight of material is added in the form of a clean solution, and during the process of mixing is frequently heated up to from 90° to 100° F. to accelerate the rapidity of the bleaching. The stuff is then emptied into a stuff chest built of brickwork lined with cement and furnished at the bottom with perforated draining tiles. The following table gives the yield of bleached half-stuff from different kinds of rags, and loss occasioned by boiling and bleaching:—

	Yield of Half Stuff. Per Cent.	Loss on Treatment. Per Cent.
Best new cotton pieces .	88·0	12·0
Low ,, ,, ,, .	80·1	19·9
Cotton rags, No. 1 .	88·0	12 0
,, ,, ,, 2 .	86·1	13·9
,, ,, ,, 3 .	83·2	16·8
,, ,, ,, 4 .	73·0	27·0
New unbleached cotton .	63·5	36·5

When the bleach has exhausted itself, taking from ten to twenty-four hours, the liquor is allowed to drain off, and the bleached half-stuff is dug out and dumped into the beaters, where it is reduced to the state of ultimate fibres by the action of the beating roll preparatory to making into paper.

The character of the paper produced is largely influenced by the conditions of beating, as well as by the subsequent treatments during boiling, etc. The chief uses for cotton are in the manufacture of blotting papers, filter papers, high-class writing papers, *éditions de luxe*, banks, loans, bonds, ledgers, and nearly all hand-made papers. It is practically impossible to find a paper on the market consisting wholly of either cotton or linen; the two materials are mixed together in various proportions, and sometimes chemical wood pulp is added.

In the manufacture of blottings, soft tender rags, such as muslins, are used, frequently boiled in lime, and left heaped up after boiling, to allow them to ferment and get tender. After the usual breaking-in, washing, beating, etc., the material is specially beaten. The knives of the beater roll are made of steel and kept sharp, and the beating conducted as quickly as possible, and in such manner as to cut the fibres asunder rather than to draw them out and mutilate them. The beaten material, when passed over the machine, gives rise to a soft, spongy, bibulous paper; containing, on an average, two-thirds of air space. The writer has endeavoured to trace the relationship between the air space or "bulk" of blotting papers and their power of capillary attraction as measured by the method of holding a strip of paper vertically with its bottom

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edges dipped under water, and noting the number of mm. rise during the period of one minute. The results are given in the annexed table.

Table showing the connection between the air space and bulk of different makes of blotting paper, and their power of capillary attraction:

Sample	Wt. per cc.	Percentage Volume.		Bulk.	Capillarity expressed in number of mm. water rises during 1 minute.		
		Fibre.	Air.		X.*	Y.*	Mean.
1	·550	36·6	63·4	2·73	22	20	21
2	·479	32·0	68·0	3·13	31	31	31
3	·488	32·5	67·5	3·08	31	30	30·5
4	·480	32·0	68·0	3·13	30	29	29·5
5	·507	33·8	66·2	2·96	24	21	22·5
6	·586	39·7	60·3	2·52	23	21	22
7	·535	35·7	64·3	2·80	24	26	25
Mean	·518	34·6	65·4	2·90			25·9

Filter paper is made somewhat after the manner of blotting paper, but with much greater precaution; for the paper has to be strong, as well as able to allow the rapid passage of liquids through its pores. For analytical work it has to be specially prepared so as to deprive it of its mineral constituents. During the last decade, however, wood pulp specially prepared and beaten has to some considerable extent taken the place of cotton, both for filter and blotting papers.

A copious supply of pure water is of primary importance to a mill making high-class papers from rags. The following table shows approximately the number of gallons of water required, at different stages of treatment, in a mill making paper from cotton rags:—

Operations.	Galls. of Water per Ton of Paper.	Percentage on Total Water Used.
		Per cent.
Boiling rags	1,100	1·4
Washing rags	37,800	45·8
Mixing bleach	200	·3
Washing out bleach	5,000	6·2
Mixing starch	40	—
Dissolving alum	20	—
Making rosin size	25	—
Scalding papers	500	·6
Beating and emptying	5,000	6·2
Auxiliary strainers	5,500	6·9
Spraying on strainer	2,300	2·9
Couch rolls, suction-boxes, wire, etc.	16,000	20·0
Washing skins	6,000	7·5
Preparing size	70	—
Rinsing strainers	100	1·2
	79,655	100·0

* The column X refers to the "machine" direction, and Y to the "cross" direction of the paper.

For purposes of comparison with the foregoing, the following table shows approximately the number of gallons of water required at the different stages in a mill making Esparto papers:—

	Gallons of Water Required per Ton of Paper.	Percentage on Total Water Used.
		Per cent.
Grass boilers	7,440	17·7
Breakers	3,224	8·0
Bleach	480	1·2
Breaker chests	3,800	9·6
Presse pâte	7,600	19·1
Beaters	9,720	24·5
Machines	7,500	18·9
Total used per ton of paper	39,764	100·0

The water consumption per ton of paper may be much greater or much less than the foregoing, and is much influenced by individual requirements. The foregoing tables must, therefore, merely be taken as typical.

A "beaterman" born and bred to the work can tell, by the feel of the half-stuff, whether he is dealing with cotton or linen stock; and he may possibly be able to tell what quality of linen or cotton he is dealing with, by plunging his hand into the material as it circulates round the beater. The general appearance of the material is also useful to the paper-maker. There is a greasiness about the linen or flax fibre which distinguishes it from cotton. Pure bleached snow-white cotton half-stuff presents a beautiful appearance, and those who are not initiated into the mysteries of paper-making are mute with astonishment when they discover that this has been produced from dirty rags which have often been cast off by the lowest grade of humanity.

Cotton, although the most inert of all vegetable fibres, and consequently the most stable and least liable to deterioration through time and atmospheric agencies, has to be manipulated with great care during the processes of treatment, to avoid oxidation and destruction of the fibre. When once such oxidation is produced, cotton fibre is no longer in its stable condition: oxidation and destruction of such fibre contained in the paper will continue. Great care has therefore to be exercised in the process of bleaching. The temperature of the bleach liquor should never exceed 100° F., or oxidation and rotting of the fibre takes place. The author, in the course of his investigations, has discovered a

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waxy substance which is sometimes formed in bleached rags when these are heaped up. The rags become warm and develop a sweet aroma, not unlike that of beeswax. It is the result of what may be described as "fatty degeneration" of cellulose, and appears to be due to the influence of bacterial action: it is only produced under peculiar conditions. It makes its appearance quite unexpectedly. The rags themselves contain only small quantities of the waxy substance so formed, but it is often separated in considerable quantities from the rags when they are disintegrated in the "breaker." It is seen to mechanically detach itself from the fabric, to form a film on the surface of the water, which in course of time builds itself up in a thick transparent layer on the sides of the breaker, and is found associated with alumina, iron, and lime salts. This wax-like substance generally resembles beeswax in appearance. It is soluble in ether, and has a saponification equivalent of 19·46 (KOH), and a very definite melting point of 47·5° C. The wax, on saponification, is found to give 91·04 per cent. of insoluble fat acids. Samples taken at different times are found to resemble one another very closely in composition. This product must be formed after the bleaching, as it is completely soluble in soda, and would have been entirely removed had it existed in the rags prior to the boiling. One batch of cotton fibre, which smelt strongly of this substance when treated with alcohol, gave 2·87 per cent. of extract, and, subsequently treated with ether, 0·73 per cent. The author collected as much as 50 lbs. of this deposit, which was found on extraction with ether to contain 77·54 per cent. of the wax.

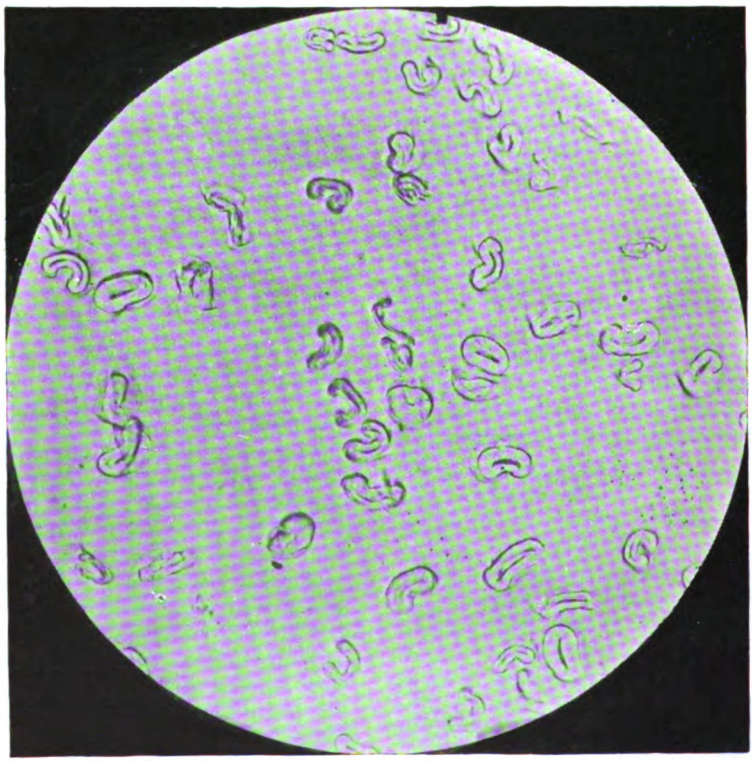

FIG. 8.—TRANSVERSE SECTION OF COTTON FIBRES.
(*Magnified 300 diameters.*)

(*To be continued.*)

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THE CONTINUOUS-CURRENT DYNAMO.

PART VI.

By H. M. HOBART, M.I.E.E.

THE principal electro-technical considerations requiring to be understood, in order to design continuous-current dynamos, have been briefly explained in these articles. Although the student who has mastered these principles, would doubtless feel confident that he could design a *good* dynamo; he would, nevertheless, not know how to proportion the machine in order to ensure obtaining the *best* result for a given expenditure. Some designers have striven to attain this result by the use of rules and formulæ; such, for example, as starting from the basis of the peripheral speed, or from some formula in which the alleged correct armature diameter is expressed in terms of the output, voltage, speed and temperature rise.

The writer is emphatically of opinion that these are comparatively unsatisfactory methods, and is convinced that far better results may be obtained by an altogether different procedure, which he proposes to explain in this closing article.

Let the problem consist in determining economical proportions for a 250 kilowatt, 250 volt dynamo, to run at 250 r.p.m. and to have the general thermal constants, commutation properties, and overload capacity already set forth as consistent with present-day requirements. A few trial calculations of the roughest nature will show that the machine should have 6 or 8 poles. Excellent designs for this output and speed may be arranged with either of these two numbers of poles. An exhaustive comparison is essential to decide between them, and, in the end it will be largely a question of individual preference, as the advantages and disadvantages are so closely balanced. It will subsequently appear that time has not been wasted in thoroughly studying the characteristics of both six and eight-pole designs, since other than the design chosen for this particular rating will be serviceable, and indeed preferable for other ratings.

We shall first devote our attention to a group of five 6-pole designs worked out for armature strengths ranging from 3,000 to 11,000 ampere-turns per pole piece. It may be objected that both the lower and the upper limit are obviously wrong; the writer would reply, that to a certain extent this is a fair objection to raise; and although he proposes to ultimately show further justification for his course in this respect, it will suffice now to state that a study of extremes is essential to a determination of the correct intermediate design.

The electro-technical calculations for the five 6-pole designs illustrated in Fig. 50*a*, are set forth in Table IV.*

Numerous interesting comparisons could be derived from Table IV., by plotting curves of reactance voltage, efficiency, peripheral speed of commutator, etc., in terms of the armature strength per pole, or in terms of the effective length of armature core, or even in terms of the total magnetic flux, M. It will, however, be best to proceed at once to Table V. in which a group of four 8-pole designs for the same rating (illustrated in Fig. 50*b*) are set forth. In these designs the armature strengths range from 3,050 to 8,800 ampere-turns per pole.†

There is one important consideration still essential to a comparative study of the designs in Tables IV. and V. This is the important consideration of *Total Works Cost.* The determination of the Total Works Cost is a department of factory work in which it has become traditional that the designing engineer shall not concern himself. It is the practice to place this cost determination in the charge of a man entirely unacquainted with designing work. The result has been to seriously embarrass the designer, for the ultimate problem in designing, is to obtain the best possible result for a given outlay; or—conversely—to obtain a required result at a minimum outlay. Hence, to be obliged to suspend his work for a day, or often much longer, pending the preparation, by the cost department, of a presumably correct estimate of the Total Works Cost of his design, was a very great drawback to the designing engineer; for by this slow process, weeks could and often did elapse before he was in possession of comparative estimates of several alternative designs. The consequence has been, that designing engineers have, except in especially important cases, put in hand a design which, so nearly as they could judge from an estimate of the net effective material, and from their own general notions of the attendant cost for labour, and from a due consideration of the prejudices and traditions of the factory management, was the cheapest practicable to propose for the required purpose.

* For Table IV. see p. 584. † For Table V. see p. 580.

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Recognising the futility of obtaining rational results under such a regime, the writer has examined into this matter, and has developed a method of estimating the Total Works Cost, which, while certainly more trustworthy than the methods of non-technical cost departments, is so simple and expeditious as to enable the designing engineer to estimate the Total Works Cost of a given design, as readily as he estimates the magnetomotive force, the heating, or the commutation constants.

This method may be briefly described as follows :—

The Total Works Cost is made up of two components: the cost of the effective material, which may be calculated as usual; and the non-effective cost, which includes the non-effective material, and also labour and other items. This non-effective cost depends, as comparison of different machines has shown, upon the overall diameter of the machine and upon the effective length, and may be expressed by the following equation :—

Non-effective cost (in shillings)

$$= 0{\cdot}10\ D_1^2 + 0{\cdot}18\ D_1\ \lambda_n$$

where D_1 = *overall* diameter of the machine in cms., and

λ_n = *effective* length of the armature core in cms.

Of course the constants will vary to a certain extent for different firms, according to wages paid and according to the facilities of

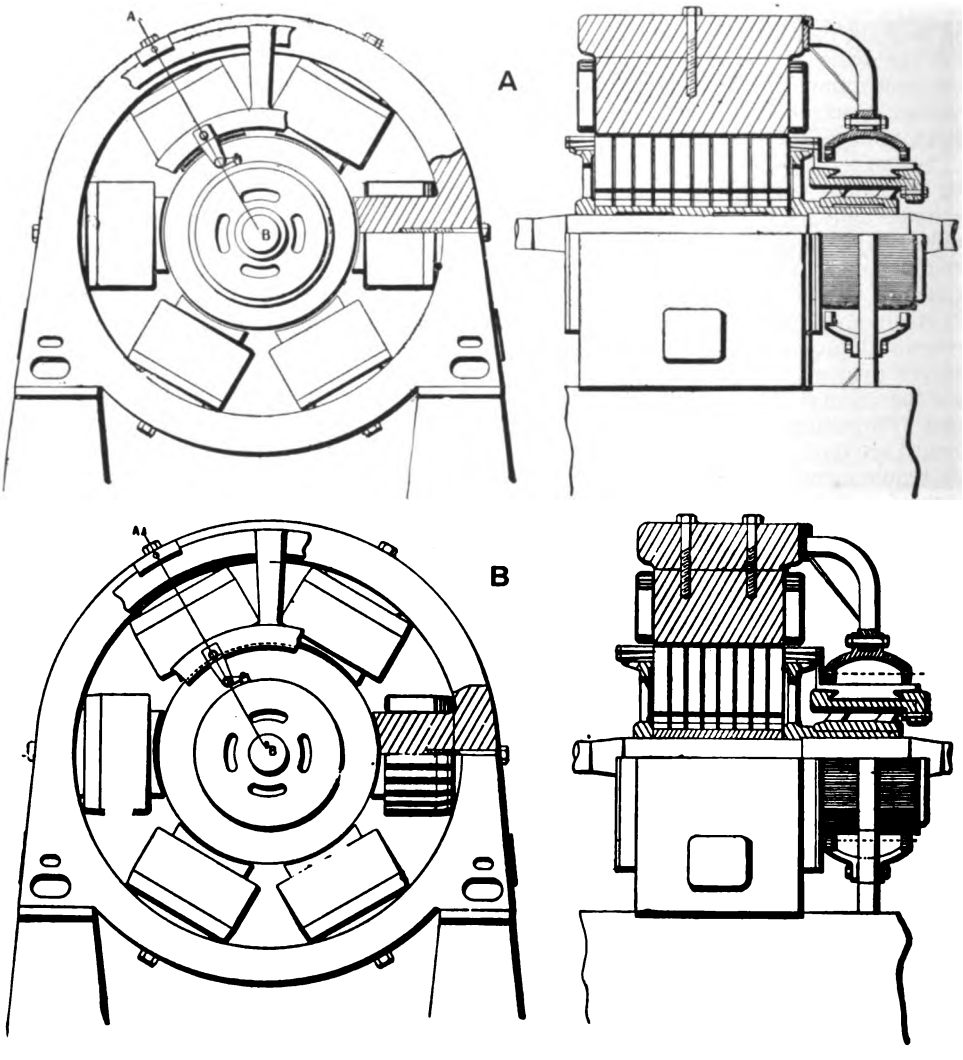

FIG. 50*a*.—DESIGNS FOR SIX-POLE DYNAMOS.
(*For dimensions, see Table IV., p.* 584.)

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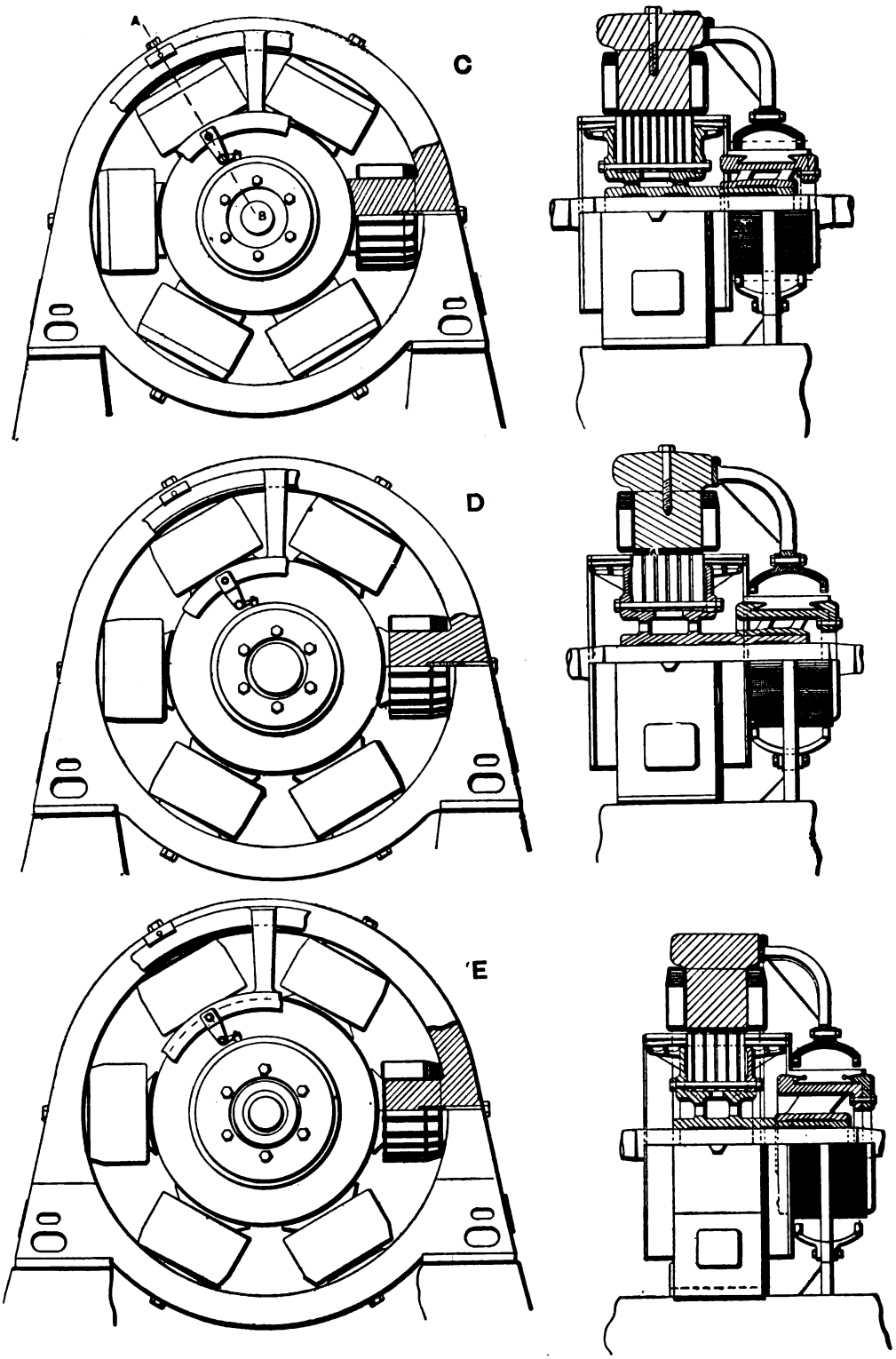

FIG. 50*a*.—DESIGNS FOR SIX-POLE DYNAMOS (*continued*.)
(*For dimensions, see Table IV., p.* 584.

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the firm, but they should be nearly constant for large and small machines.

An application to the first 6-pole design (Column A of Table IV.) is shown in Table VI., in the form of a tabulated specification:—

TABLE VI.

Overall diameter D_1 in cm.	180
Effective length λ_n in cm.	65
$0{\cdot}10\ D_1^2$	3260
$0{\cdot}18\ D_1\ \lambda_n$	2100
Non-effective cost	5360
Cost of effective material	6000
Total cost of machine (in shillings)	11360

By this means the Total Works Cost of the five 6-pole, and four 8-pole designs have been obtained, and are set forth in Table VII.

In Fig. 62 (p. 582) are plotted two curves, showing respectively, in terms of the armature ampere-turns per pole, the total factory cost of the six and eight-pole designs. Were the designs of equal merit, one would obviously

TABLE VII.

No. of Poles.	Armature Ampere-turns per pole.	$0{\cdot}10\ D_1^2$.	$0{\cdot}18\ D_1\ \lambda_n$.	Non-effective Cost.	Cost of effective material.	Total Works Cost (in Shillings).
6	3000	3260	2100	5360	6000	11360
6	5000	3400	1400	4800	4600	9400
6	7000	3600	1000	4600	3970	8570
6	9000	3600	850	4450	3710	8160
6	11000	3700	700	4400	3840	8240
8	3000	3750	1480	5230	5030	10260
8	5000	3900	970	4870	3930	8800
8	7000	4100	760	4860	3610	8470
8	9000	4100	620	4720	3730	8450

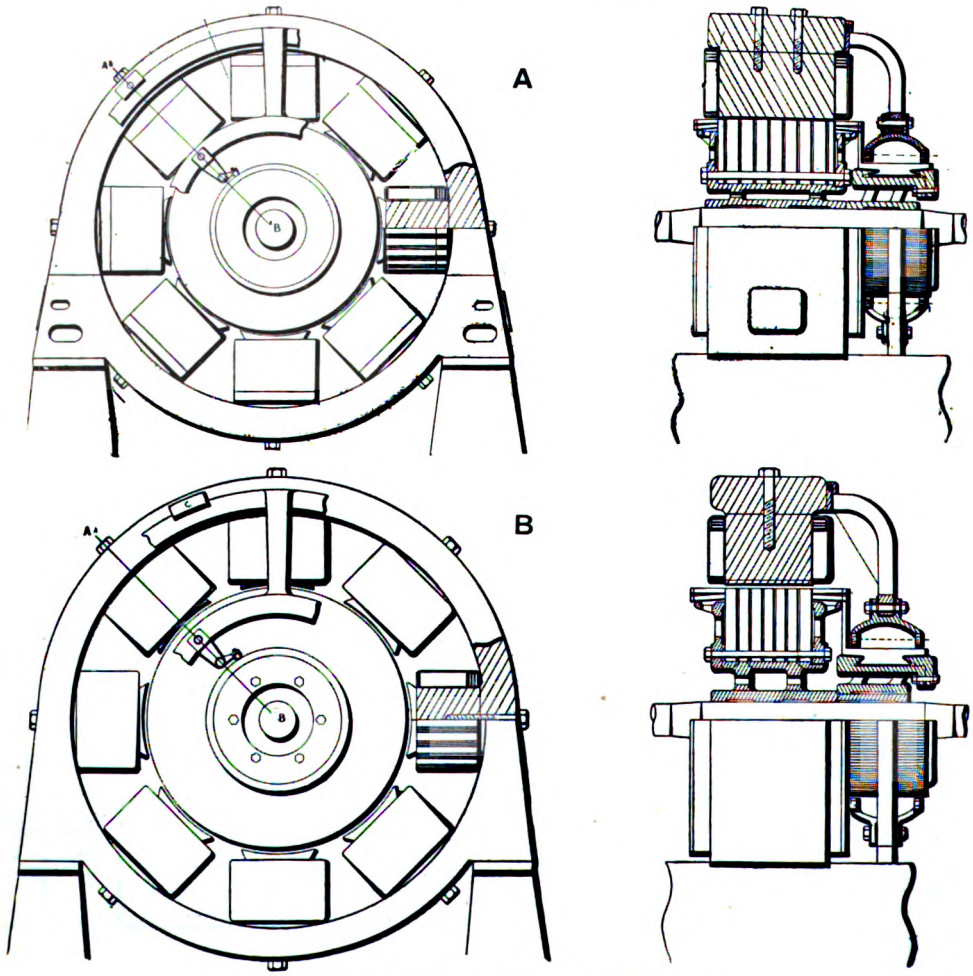

FIG. 50*b*.—DESIGNS FOR EIGHT-POLE DYNAMOS.
(*For dimensions, see Table V., p.* 586.)

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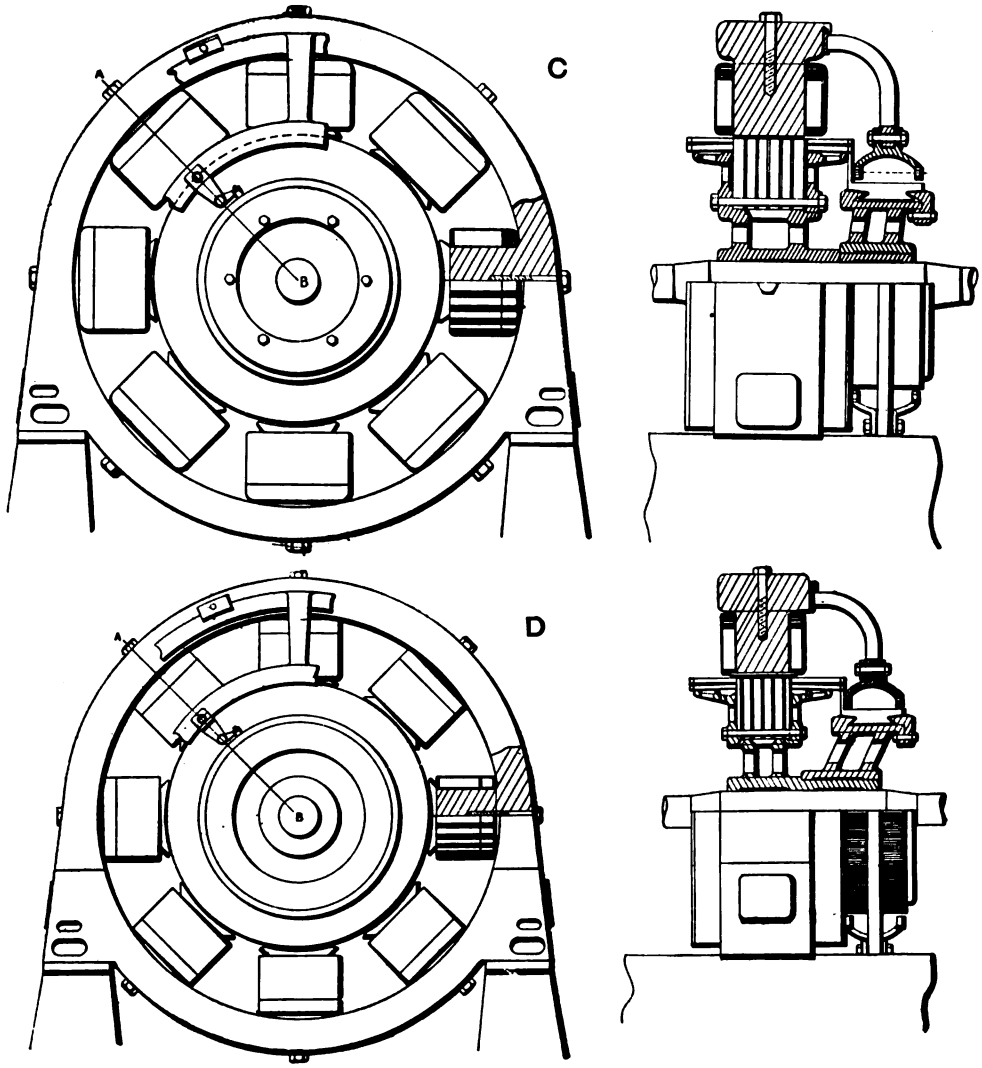

FIG. 50*b*.—DESIGNS FOR EIGHT-POLE DYNAMOS (*continued*).
(*For dimensions, see Table V., p.* 586.)

at once determine upon a six-pole design with 10,000 armature ampere-turns per pole, as the economically correct machine to build. But the relative technical merits of the design must be considered, and foremost amongst these is the question of the reactance voltage. The reactance voltages of these different designs are plotted in the curves of Fig. 62A, and we find that for a given number of poles, the designs with the lowest reactance voltage are, for this rating, more expensive. One point, however, which it is important to note is, that if we can afford to work up toward the left on our cost curves of Fig. 62, the eight-pole design is not only cheaper, but has a slightly lower reactance voltage than the six-pole design. At 7,000 ampere-turns there is practically nothing to choose between them, so far as relation to cost and commutation; and were a low cost imperative, we should turn to Tables IV. and V. to seek other comparisons. We should, for example, note that whereas the constant losses are about the same (see column C of both tables), the variable losses are 800 watts less in the six-pole design. This, however, is an almost negligible difference, so that, so far as relates to the efficiency at all loads, the designs are practically equivalent. The peripheral speed of the commutator is considerably less in the six-pole design, but is so very low in both designs that here again the difference is of but

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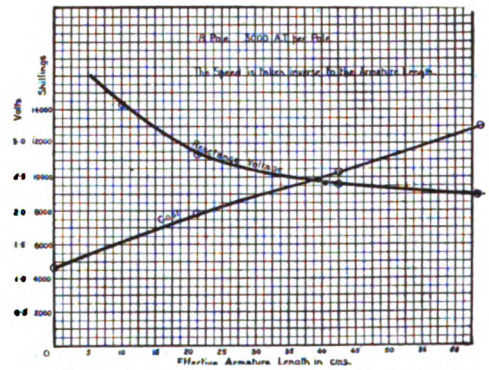

FIG. 51.—8 *pole*, 3,000 *Arm.* A.T. *per pole.*

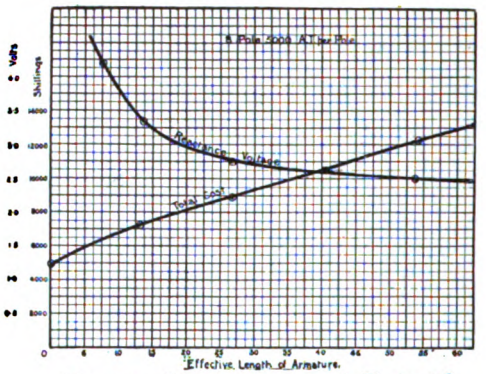

FIG. 52.—8 *pole*, 5,000 *Arm.* A.T. *per pole.*

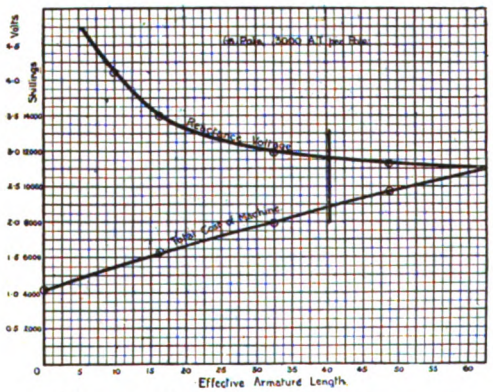

FIG. 55.—6 *pole*, 3,000 *Arm.* A.T. *per pole.*

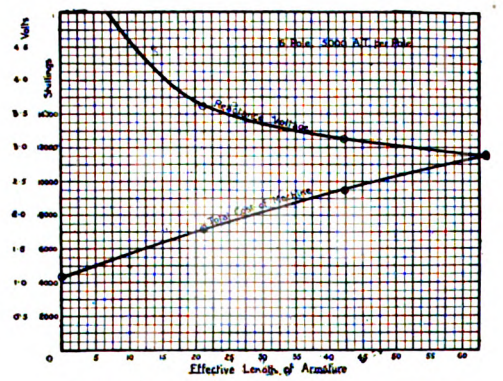

FIG. 56.—6 *pole*, 5,000 *Arm.* A.T. *per pole.*

COST AND REACTANCE

slight importance. Hence the case stands thus: a very slightly lower reactance voltage for the eight-pole machine, to offset against very slight superiority in efficiency and a lower peripheral speed of commutator in the six-pole design.

Were excellence of commutation so important as to justify considerably higher cost, one would at once determine upon the eight-pole design, for at lower armature strengths the difference in cost is considerable, amounting at 3,000 ampere-turns per armature pole, to 10%. But this design would cost 21% more than the cheapest eight-pole design, and 28% more than the cheapest six-pole design.

Failing any special conditions, a sound decision would be to select the eight-pole design with 5,000 armature ampere-turns, *i.e.*, that set forth in column B of Table V.

It may seem a very tedious process to go through such complete calculations in a search for the right design, but another consideration comes in to further justify the method.

Experience in designing shows, and curves will be deduced in support of this contention, that, given a correct design for a given output, voltage and speed, a close approximation to a correct design for the same output and voltage, but for a different speed, will be obtained by altering the effective core length in inverse proportion to the change in speed.

Non-compliance with this proposition is one of the greatest errors which designers are now-a-days committing. The erroneous alternative which they often choose, is to design for constant peripheral speed: they justify this practice on the plea that one obtains the greatest output from a given expenditure for material, by revolving it at high speed. This is true for the cost of effective material, but from the method of analysing costs already set forth, it is evident that the non-effective cost is generally a large component of the total cost, and is generally greater the higher the peripheral speed. Hence, one must consider these two tendencies, and work out that peripheral speed which gives the minimum *total* cost. This is roughly the case when one follows the proposition above enunciated, as to altering the effective core length in inverse proportion to the change in speed. The proposition must, however, be interpreted liberally. For slight changes in speed it may

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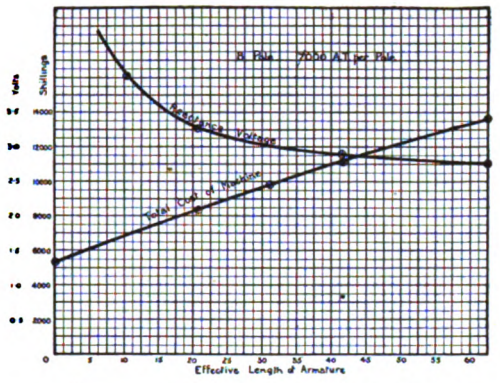

FIG. 53.—8 *pole*, 7,000 *Arm.* A.T. *per pole.*

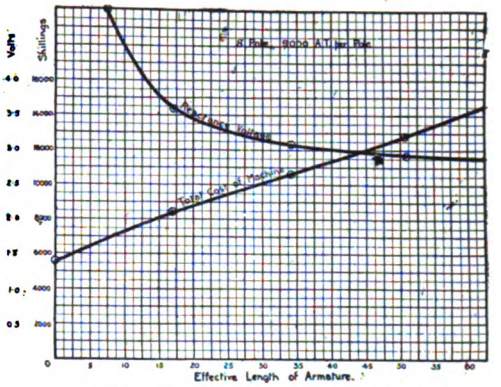

FIG. 54.—8 *pole*, 9,000 *Arm.* A.T. *per pole.*

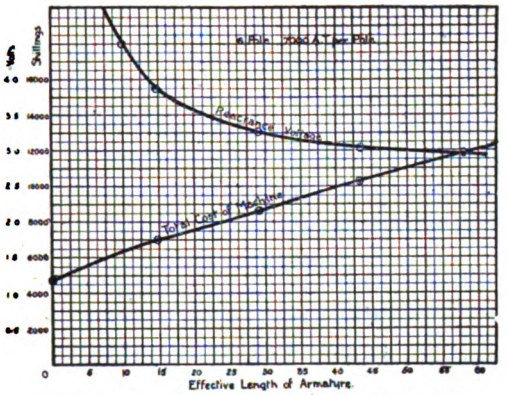

FIG. 57.—6 *pole*, 7,000 *Arm.* A.T. *per pole.*

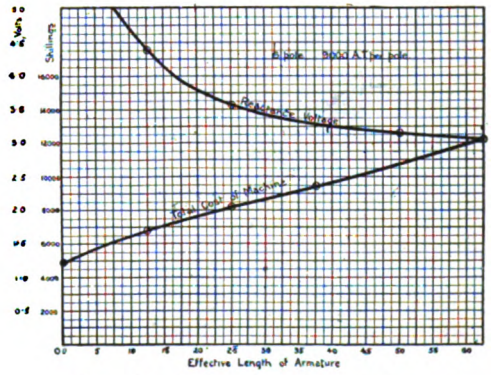

FIG. 58.—6 *pole*, 9,000 *Arm.* A.T. *per pole.*

VOLTAGE OF DYNAMOS.

be rigorously followed; for great changes in speed (say from 250 r.p.m.), one would work, not from the ideal design for 250 r.p.m. (say column B of Table V.), but from one or other of the adjacent designs, going to the left-hand column for the basic model from which to narrow the core for higher speed designs, and going to the next column at the right for the basic model from which to widen the core for lower speed designs, and going still further to the right for the case of designs for still lower speeds. At sufficiently low speeds, a ten-pole design would be preferable. Similarly, at sufficiently high speeds, one would work from the six-pole designs, and at *excessively* high speeds the six-pole designs would no longer suffice, and one would resort to four-pole designs. But for a speed range of 3 to 1 or even greater, practical results are obtained by proportional changes in the effective core length of a single design.

In accordance with this plan, the curves in Fig. 55 have been plotted from the basis of the design in column A of Table IV. The original design had an effective core length of

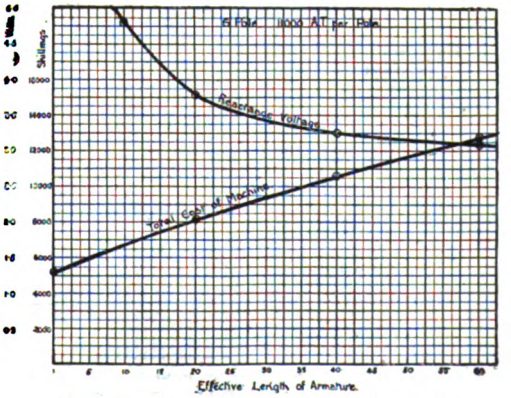

FIG. 59.—6 *pole*, 1,000 *Arm.* A.T. *per pole.*

650 mm., and gave 250 k.w. and 250 volts at 250 r.p.m. From the curves, we may ascertain the cost and reactance voltage of derived machines for other speeds. Thus, for 405 mm. core length, the output and voltage would remain the same, and the speed would be 400 r.p.m. The cost would be 9,000 shillings and the reactance voltage would be 2·9 volts.

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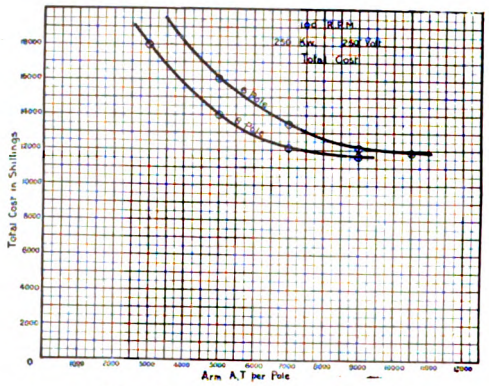

FIG. 60.—100 R.P.M.: *Total Cost.*

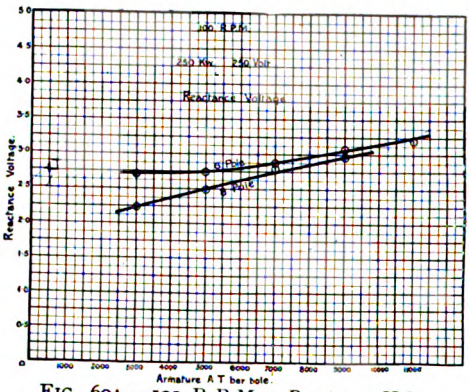

FIG. 60A.—100 R.P.M.: *Reactance Voltage.*

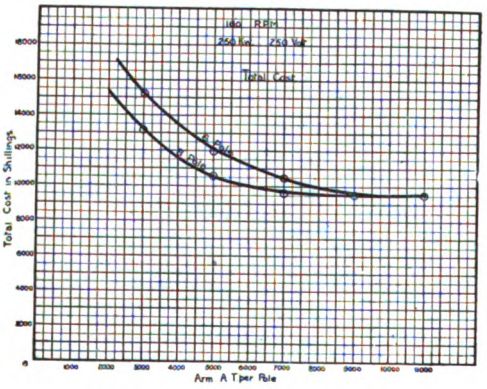

FIG. 61.—160 R.P.M.: *Total Cost.*

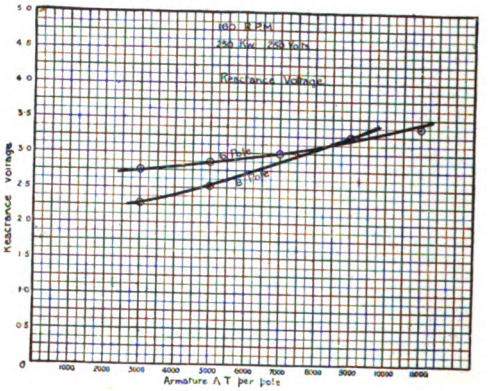

FIG. 61A.—160 R.P.M.: *Reactance Voltage.*

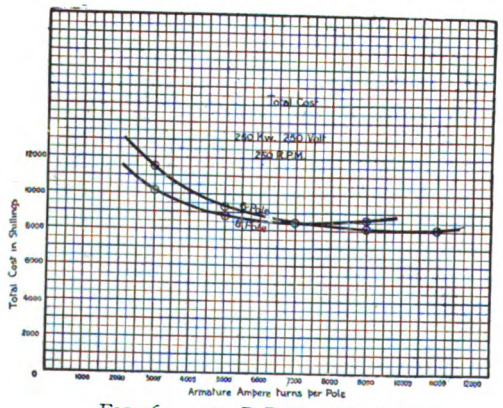

FIG. 62.—250 R.P.M.: *Total Cost.*

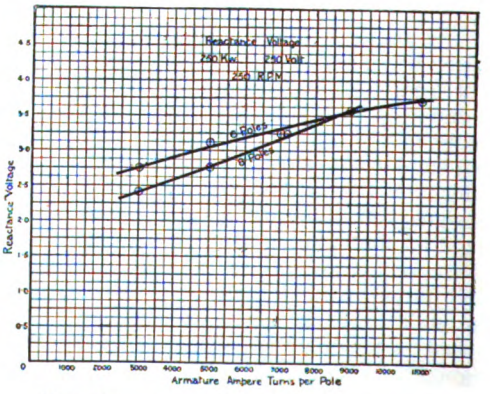

FIG. 62A.—250 R.P.M.: *Reactance Voltage.*

TOTAL COST AND REACTANCE VOLTAGE OF SIX AND EIGHT-POLE DYNAMOS.

The peripheral speed of the commutator would be 12·6 meters per second, still a low value. Nevertheless, one would not, without further investigation, decide upon this design. The further investigation generally requires the preparation, from the remaining eight basic designs, of eight sets of curves corresponding to the curves of Fig. 55. These are shown in Figs. 51 to 58. Then, returning to the question of the required 250 k.w., 250 volt, 400 r.p.m. design, one would prepare the curves shown in Figs. 63 and 63A.

A study of these curves shows that the 8-pole designs are but little superior to the 6-pole designs with respect to cost and commutation, and the peripheral speeds of

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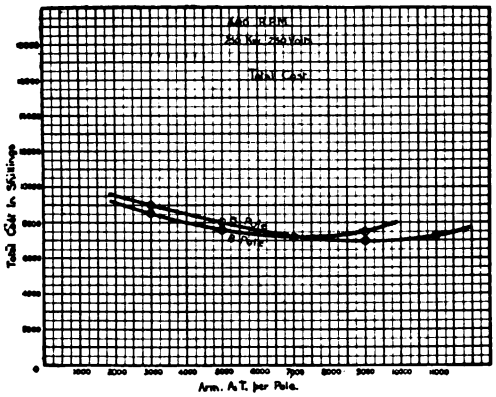

FIG. 63.—400 R.P.M. : *Total Cost.*

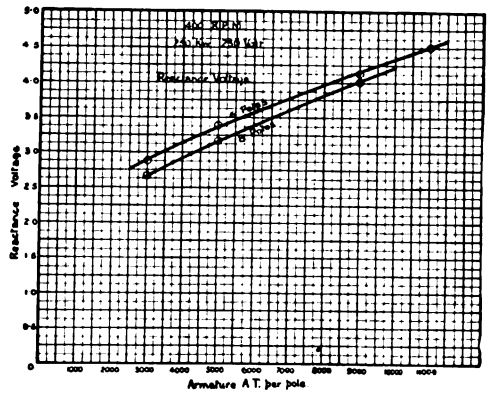

FIG. 63A.—400 R.P.M. : *Reactance Voltage.*

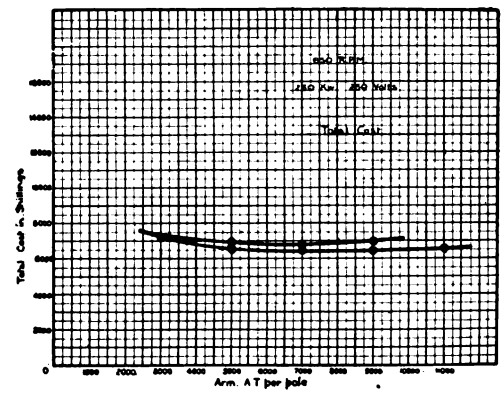

FIG. 64.—650 R.P.M. : *Total Cost.*

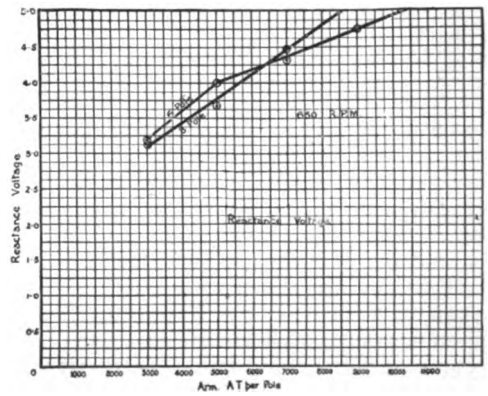

FIG. 64A.—650 R.P.M. : *Reactance Voltage.*

TOTAL COST AND REACTANCE VOLTAGE OF SIX AND EIGHT-POLE DYNAMOS.

the 8-pole designs would be approaching values which, although by no means prohibitively high, would nevertheless prejudice commutation to a greater extent than would the slightly higher reactance voltage. The 6-pole design in column B, costing 8000 shillings and with a reactance voltage of 3·3 volts, would be a rational choice, and one involving an outlay but 14% in excess of the very cheapest design.

Similar considerations would control the choice of designs for this output and voltage, but for other speeds, and the corresponding curves are given in Figs. 60, 60A, 61, 61A, 62, 62A, 63, 63A, 64 and 64A.

The method described for determining the Total Works Cost, although certainly very brief, may, for rough estimations, be replaced by a still simpler method. It is an established fact,* that for a given type and voltage the Total Works Cost is truly proportional to the product of armature diameter D, and "equivalent length of armature winding over end connections" L. Now as the construction of the end connections is varied greatly by different manufacturers and in different types of machine, it is convenient to substitute $\lambda_g + 0{\cdot}7\,\tau$ for L;

$$\therefore L = \lambda_g + 0{\cdot}7\,\tau$$

$$\text{Total Works Cost} = K \times D \times L$$

$$\text{T.W.C.} = K \times D \times (\lambda_g + 0{\cdot}7\,\tau).$$

K is a function of the voltage and type.

D, λ_g and τ are expressed in centimeters, and T.W.C. is expressed in shillings.

The value of K may be readily determined for the designs set forth in Tables IV. and V. This determination is carried out in Tables VIII. and IX.

Thus for continuous-current dynamos of this range of voltage and dimensions, the

* See "Electrician" for September 11th, 1903, page 840; and "Elektrotechnische Zeitschrift" for October 1st, 1903, page 821; and a paper by the author, entitled "The Rated Speed of Electric Motors as affecting the type to be employed," read before the Institute of Electrical Engineers, March 10th, 1904.

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TABLE VIII.—Determination of K for the five 6-pole designs of Table IV.

	A.	B.	C.	D.	E.
T. W. C. from Table VII. (in shillings)	11460	9400	8570	8160	8160
D (in centimeters)	80·0	90·0	95·0	100	105
λ_g ,, ,,	81·0	53·6	38·0	33·0	27·0
τ ,, ,,	42·0	47·2	50·0	52·5	55·0
$0{\cdot}7\,\tau$ . .	29·4	33·0	35·0	36·7	38·5
$\lambda_g + 0{\cdot}7\,\tau$.	110·4	86·6	73·0	69·7	65·5
$D \times (\lambda_g + 0{\cdot}7\,\tau)$	8800	7800	6940	6970	6900
$K = \frac{\text{T.W.C.}}{D \times (\lambda_g + 0{\cdot}7\,\tau)}$	1·29	1·21	1·24	1·17	1·19
Mean value of K . .	1·22				
Percentage deviation from mean value of K . .	6%	1%	2%	4%	3%

TABLE IX.—Determination of K for the four 8-pole designs of Table V.

	A.	B.	C.	D.
T. W. C. from Table VII. (in shillings) .	10360	8850	8470	8450
D (in centimeters) .	100	110	115	120
λ_g ,, ,, .	55·0	36·0	28·0	24·0
τ ,, ,, .	39·3	43·2	45·2	47·2
$0{\cdot}7\,\tau$ . . .	27·5	30·3	31·7	33·1
$\lambda_g + 0{\cdot}7\,\tau$ . .	82·5	66·3	59·7	57·1
$D \times (\lambda_g + 0{\cdot}7\,\tau)$.	8250	7300	6870	6850
$K = \frac{\text{T. W. C.}}{D \times (\lambda_g + 0{\cdot}7\,\tau)}$	1·25	1·21	1·23	1·23
Mean value of K .	1·23			
Percentage deviation from mean value of K . . .	2%	2%	0%	0%

value for K may be taken as 1·23 shillings; and it will be noted that in none of the nine designs, taking K = 1·23, does the D × L method of determining the Total Works Cost lead to a result differing by more than 5% from the value already deduced in Table VII. by the first method.

The influence of the voltage and speed upon the value of K is very interesting. In general, it may be said that K decreases with increasing voltage, owing to the smaller proportion which the cost of the commutator bears to the total cost. For 500-volt machines designed, as in these cases, with a high loading of the armature periphery with ampere-conductors, the values of K would lie between the limits 1·05 and 1·15. This does not mean that 1·10 and 1·23 indicate the relative costs of 500-volt and 250-volt machines *for a given rated output*, but it indicates the ratio of the costs when consistent ratings are given to designs with the same value of D × L, but with windings and commutators designed for these two voltages. In general, the 500-volt machine will have the lower rating.

By carrying out corresponding designing campaigns for 250-volt machines, for 100 k.w., 160 k.w., 400 k.w. and 650 k.w., one would have a stock of designs from which an intelligent estimate for intervening ratings could readily be obtained by interpolation.

Applying the conclusions derived from these comparative studies of groups of alternative designs, it will be evident that continuous-current dynamos may be built for moderately high speeds and still with fairly low reactance voltage, but such designs will be subject to high centrifugal forces, and the mechanical difficulties will hence be greatly increased. Thus in the design of high-speed continuous-current dynamos, one must choose between two evils: high reactance voltage and high centrifugal forces—and the decision will involve a compromise between these two objectionable characteristics, the one electrical and the other mechanical. Very high-speed continuous-current dynamos, if designed with out special appliances, such as compensating windings, or auxiliary poles, or smooth core windings, will, on account of these two limitations, never be thoroughly successful as regards commutation.

TABLE IV.—6-Pole Designs for 250 K.W. Dynamo.

	A	B	C	D	E
Number of Poles .	6	6	6	6	6
Kilowatts . . .	250	250	250	250	250
Revs. per Min. . .	250	250	250	250	250
Frequency in Cycles per Sec. . . .	12·5	12·5	12·5	12 5	12·5
Terminal Volts. .	250	250	250	250	250
Amperes full load .	1000	1000	1000	1000	1000
DIMENSIONS (In Mms.)					
ARMATURE.					
External Diameter (D)	800	900	950	1000	1050
Diameter at the bottom of the slots	720	810	854	904	942
Internal diameter of the Laminations .	303	422	451	524	559
Gross Axial length of Core between Flanges (λg) . .	810	536	380	330	270
Number of Ventilating ducts . .	9	7	6	5	5
Width of each ventilating duct . .	10	10	10	10	10
Effective length of Armature Core (λn)	650	420	290	250	200
Number of Slots .	54	90	84	78	78
Dimensions of Slot.	40×12·4	45×12·4	48×14·5	48×18·0	54×19
Width of Tooth at the root . . .	29·5	15·8	17·4	18 2	18·9

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TABLE IV.—*continued.*

	A	B	C	D	E
Width of Tooth at the top	34·1	19·1	22·1	22·1	23·4
MAGNET CORE.					
Radial depth of the Air Gap	6	6·5	7·0	7·5	8·0
Polar Pitch (τ)	427	477	503	530	558
Pole Arc	299	334	352	371	390
Ratio of Pole arc to Pole pitch	·7	·7	·7	·7	·7
Length of Pole face parallel to the Shaft	810	536	380	330	270
Radial Length of the Magnet Core	340	320	315	300	300
Width of Magnet Core parallel to the Shaft	300	340	355	320	290
Width of Magnet Core at right angles to the Shaft	820	480	355	320	290
Cross section of Magnet Core—sq cms.	2260	1380	985	800	645
YOKE.					
External diameter	1808	1838	1898	1890	1928
Internal diameter	1490	1550	1590	1610	1660
Thickness of Yoke	159	144	154	140	134
Axial Width	900	600	400	360	300
Effective Cross-section of Yoke (*i.e.* 2 × one side)	2850	1720	1230	1000	809
COMMUTATOR.					
Diameter	600	600	600	600	700
Numberof Segments	108	180	252	312	390
Width of segment + insulation	17·4	10·4	7·5	6	5·65
Width of Segment (less insulation)	16·8	9·6	6·7	5·2	4·8
Effective length of Segment (from External End to Armature Connection)	400	400	400	400	360
BRUSHES.					
Number of Sets	6	6	6	6	6
Number per Set	8	8	8	8	8
Width of the Brushes	32	32	32	32	32
Length of the Arc of Contact	22	22	22	22	22
TECHNICAL DATA.					
Number of face Conductors	216	360	504	624	780
Conductors per Slot	4	4	6	8	10
Number of Circuits	6	6	6	6	6
Style of Winding			parallel-		
Mean length of one armature turn (in cm.)	262	224	202	200	193
Total Armature Turns	108	180	252	312	390
Turns in Series between brushes	18	30	42	52	65
Length of circuit between brushes (cms.)	4710	6740	8480	10400	12600
Cross section of one Armature Conductor (sq. cms.)	55·5	56	56	56	56
Number of Conductors in parallel between brushes	6	6	6	6	6
Total copper Cross-section between brushes	333	336	336	336	336
Resistance between brushes at 60° C	·00283	·00409	·0051	·0062	·0075
Volts drop in Armature at 60° C	3	4·2	5·2	6·3	7·6
Volts drop in Brush Contact	2	2	2	2	2
Volts drop in Series Winding	·8	·7	·95	1·05	1·15
Total Internal Volts drop	5·8	6·9	8·2	9·4	10·8
Internal voltage	255·8	256·9	258·2	259·4	260·8

	A	B	C	D	E
COMMUTATION, (according to Method II.)					
Average Voltage between Commutator Segments	13·9	8·3	6·0	4·8	3·85
Turns per Segment	1	1	1	1	1
Output of armature (induced Volts × Amps.)	257000	257000	257000	257000	257000
λn (in cm)	65	42	29	25	20
·15 τ (in cm.)	13·2	14·6	14·4	15·0	15·3
λn + ·15 τ (in cm.)	78·2	56·0	43·4	40·0	35·3
Number of Poles	6	6	6	6	6
Flux entering armature per Pole (Megalines)	28·5	17·2	12·3	10	8·09
Reactance Voltage	2·75	3·14	3·24	3·58	3·8
MAGNETIC DATA AT FULL LOAD.					
Density in Armature Iron	10500	10500	10500	10500	10500
Corrected density in Teeth	21200	21500	21400	20700	20400
Density at pole Face	11400	9250	8960	8200	7700
Density in Magnet Core	15150	15000	15000	15000	15000
Density in Yoke	12000	12000	12000	12200	12000
AMPERE TURNS.					
Armature Core	115	115	115	115	115
Teeth	2000	2600	2740	2000	2160
Air Gap	5500	4800	5000	4900	4900
Magnet Core	1220	1120	1100	1050	1050
Yoke	640	640	670	670	700
COMPOUNDING.					
Total Ampere turns per Pole on Armature	3040	5080	7100	8800	10950
Displacement of Brushes in per cent. of Pitch	4	5	6	8	10%
Demagnetising ampere turns	240	508	860	1400	2200
Distorting ampere turns	2800	4600	6200	7400	8700
Ampere turns for overcoming Armature Reaction	940	1660	2400	3250	4400
Saturation Ampere turns	9470	9275	9625	8735	8925
Total Field Ampere turns	10410	10935	12025	11985	13325
Ampere turns for Shunt Winding	9500	9500	9500	9000	9000
Ampere turns for Series Winding	1200	2100	2800	3600	4800
SHUNT SPOOL WINDING.					
Radial depth of Winding (in cms.)	5·5	6·0	6·0	6·5	7·0
Internal Periphery of Spool (in cms.)	201·5	135	115	103	94
External Periphery of Spool	236	172·5	152	145	138
Mean Length of one Turn (in meters)	2·19	1·55	1·34	1·24	1·16
No. of Turns per Spool	580	840	950	1010	1110
Cross-section of one turn (sq. cms.)	·118	·084	·071	·062	·06
Res. of one Spool at 60° C	2·1	3·1	3·5	3·9	4·3
Res. of all Spools at 60° C	12·6	18·6	21	23·4	25·8
Voltage drop in Rheostat	42	42	42	42	42
Voltage per Shunt Spool	34·7	34·7	34·7	34·7	34·7
Current in Shunt Winding	16·4	11·2	10·0	8·9	8·1
Ampere-turns per Spool	9500	9500	9500	9000	9000
Watts per Spool	570	390	350	310	280
Cylindrical Surface per Spool in sq. dcm.	59	40·5	33·2	28·2	26
Watts per sq. dcm.	9·6	9·6	10·5	11	10·8

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TABLE IV.—*continued.*

	A	B	C	D	E
SERIES WINDING.					
Current in Diverter	400	300	300	280	200
Current in Series Winding	600	700	700	720	800
Number of Turns of Series Winding	2	3	4	5	6
Cross-section of one Turn (sq. cms.)	5·0	6·1	5·1	5·1	6·0
Resistance per Spool at 60°C	·00020	·000164	·000228	·000255	·00025
Watts lost per Spool	75	80	111	125	157
Watts lost per sq. dcm. of cylindrical Surface	9·8	9·5	10	10·5	12·8
LOSSES AND HEATING.					
Armature C^2R loss	2940	4120	5200	6400	7700
Armature Iron loss	6800	4880	3800	3260	2840
Total Armature loss	9740	9000	9000	9660	10340
Cylindrical Surface of Armature Winding	256	238	216	224	220
Watts per sq. dcm. of Armature Winding	38	38	41·5	43	47
Current density at Brush (amps. per sq. dm.)	6	6	6	6	6
C^2R loss in Brush Contact	2000	2000	2000	2000	2000
Brush pressure in kg. per sq. cm.	·1	·1	·1	·1	·1
Friction Coefficient	·3	·3	·3	·3	·3
Peripheral Speed of Commutator (meters, per sec.)	7·85	7·85	7·85	7·85	9·2
Friction loss of Brushes per ampere	·8	·8	·8	·8	·9
Total Friction loss of Commutator	810	810	810	810	910
Total Commutator Loss	2810	2810	2810	2810	2910
Cylindrical Surface of Commutator, sq. dcm.	75	75	75	75	80
Watts per sq. dcm. of Cylindrical Surface	37·5	37·5	37·5	37·5	36·5

	A	B	C	D	E
EFFICIENCY.					
Iron loss	6800	4880	3800	9260	2840
C^2R loss of Armature	2940	4120	5200	6400	7500
Watts lost at the Brush Contact Res.	2000	2000	2000	2000	2000
Brush Friction Loss	810	810	810	810	910
Friction loss at Bearings	2600	2400	2200	2000	1900
Watts lost in Shunt Winding	3420	2340	2100	1860	1680
Watts lost in Series Winding	450	480	666	750	940
Watts lost in Shunt Rheostat	680	470	420	370	340
Watts lost in Series Diverter Rheostat	300	200	280	290	240
Total of all losses	20000	18000	17500	17800	18400
Output at full load	250000	250000	250000	250000	250000
Input at full load	270000	268000	267500	267800	268400
Commercial efficiency at full load	92·5	93·5	93·5	93·5	93·2
Commercial efficiency at ½ load	8?%	91·0%	91·5%	92·0%	93·0%
Constant Losses	14000	10300	9300	8300	7700
Variable Losses	5700	7100	8200	9500	10,00
WEIGHTS IN KGS.					
Armature laminations (including slot area)	2200	1620	1260	1100	1000
Armature Copper	140	202	254	310	380
Commutator Segments	330	330	330	330	350
Magnet Core	3650	2100	1450	1140	920
Yoke	5800	3650	2630	2170	1800
Shunt Copper	800	582	483	417	4·0
Series Copper	120	163	160	170	240
COST OF EFFECTIVE MATERIAL IN SHILLINGS.					
Armature Copper	280	400	510	620	760
Commutator Copper	660	660	660	660	700
Spool Copper	1840	1480	1290	1170	1300
Armature Laminations	1100	810	630	550	500
Cast Iron	870	550	400	330	270
Cast Steel	1220	700	480	380	310
Total Cost of effective Material	5970	4600	3970	3710	3840

TABLE V.

8-Pole Designs for 250 K.W. Dynamo.

	A	B	C	D
Number of Poles	8	8	8	8
Kilowatts	250	250	250	250
Revs. per Min.	250	250	250	250
Frequency in Cycles per Sec.	16·7	16·7	16·7	16·7
Terminal Volts	250	250	250	250
Amperes full load	1000	1000	1000	1000
DIMENSIONS (in mms.).				
ARMATURE.				
External Diameter (D)	1000	1100	1150	1200
Diameter at the bottom of the Slots	920	1010	1060	1100
Internal diameter of the laminations	475	582	668	717
Gross Axial length of Core between Flanges (Ag)	550	360	280	240
No. of ventilating ducts	8	6	5	5
Width of each ventilating duct	10	10	10	10
Effective length of Armature Core (An)	423	270	208	170
No. of Slots	96	104	112	112
Dimensions of Slot	10·5×40	13×45	15·8×45	17·5×50
Width of Tooth at the root	19·6	17·5	13·9	13·4
Width of Tooth at the top	22·2	20·0	16·5	16·1
MAGNET CORE.				
Radial depth of Air Gap	6·0	7·0	8·0	9·0
Polar Pitch (τ)	398	438	456	477
Pole Arc	278	306	319	333

	A	B	C	D
Ratio of Pole Arc to Pole Pitch	·7	·7	·7	·7
Length of Pole face parallel to the Shaft	550	360	280	240
Radial Length of the Magnet Core	320	300	300	300
Width of Magnet Core parallel to the Shaft	550	360	265	240
Width of Magnet Core at right angles to the shaft	260	265	265	240
Cross section of Magnet Core—sq. cms.	1280	800	550	452
YOKE.				
External diameter	1944	1980	2012	2032
Internal diameter	1672	1732	1782	1832
Thickness of Yoke	135	124	115	100
Axial Width	600	400	300	280
Effective Cross-section of Yoke (*i.e.*, 2 × one side)	1600	990	690	555
COMMUTATOR.				
Diameter	600	600	800	900
Number of Segments	192	312	448	560
Width of Segment + insulation	9·8	7·5	5·6	5·05
Width of Segment (less insulation)	9·0	6·7	4·8	4·25
Effective length of Segment from External end to Armature Connection	330	330	280	280

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TABLE V.—*continued.*

	A	B	C	D
BRUSHES.				
No. of Sets	8	8	8	8
No. per Set	6	6	6	6
Width of the Brushes	32	32	32	32
Length of the arc of Contact	22	22	22	22
TECHNICAL DATA.				
No. of Face Conductors	384	624	896	1120
Conductors per Slot	4	6	8	10
Number of Circuits	8	8	8	8
Style of Winding (parallel)	lap	lap	lap	lap
Mean length of one Armature turn (in cms.)	206	180	174	176
Total Armature turns	192	312	448	560
Turns in Series between brushes	24	30	56	70
Length of circuit between brushes (cms.)	4950	7000	9700	12300
Cross-section of one Armature Conductor—sq. cms.	0·42	0 42	0·42	0·42
Number of Conductors in parallel between brushes.	8	8	8	8
Total copper cross-section between brushes	3·36	3·36	3·36	3·36
Res. between brushes at 60°C	0·00293	0·00418	0·0058	0·00735
Volts drop in Armature at 60°C	3	4·2	5·8	7·4
Volts drop in Brush Contact	2·0	2·0	2·0	2·0
Volts drop in Series Winding	·7	0·85	1·0	1·2
Total Internal Volts drop	5·9	7·1	8·8	10·6
Internal Voltage	255·9	257·1	258·8	260·6
COMMUTATION, (according to Method II.)				
Average Voltage between Commutator Segments	10·4	6·4	4·47	3·57
Turns per Segment	1	1	1	1
Output of Armature (induced Volts × Amps)	260000	260000	260000	260000
λn (in cms.)	42·3	27·0	20 8	17·0
·15 τ (in cm.)	12·1	12·6	13·2	14·2
$\lambda n + 15\tau$ (in cm.)	54·4	39·6	34·0	31·2
No. of Poles	8	8	8	8
Flux entering Armature per pole (Megalines)	16·0	9·9	6·9	5·55
Reactance Voltage	2·45	2·77	3·27	3·6
MAGNETIC DATA AT FULL LOAD.				
Density in Armature Iron	8500	8500	8500	8500
Corrected density in Teeth	20600	20400	20600	20800
Density at Pole Face	10500	9000	7720	6950
Density in Magnet Core	15000	15000	15000	14800
Density in Yoke	12000	12000	12000	12000
AMPERE TURNS.				
Armature Core	80	80	80	80
Teeth	1645	1710	1850	2250
Air Gap	5050	5050	4900	5000
Magnet Core	1120	1050	1050	1020
Yoke	600	630	660	690
COMPOUNDING.				
Total Ampere turns per pole on Armature	3050	4920	7080	8800
Displacement of brushes in per cent. of Pitch	4%	6%	8%	10%
Demagnetising Ampere turns	240	520	1120	1750
Distorting Ampere turns	2800	4320	5300	7000
Ampere turns for overcoming Armature Reaction	900	1700	2700	3700
Saturation Ampere turns	9000	9000	9000	9500
Total Field Ampere turns	9900	10700	11700	13200
Ampere turns for Shunt Winding	9000	9000	9000	9500
Ampere turns for Series Winding	1200	1950	2800	3750
SHUNT SPOOL WINDING.				
Radial depth of Winding (in cms.)	5·5	6·0	6·0	6·5
Internal Periphery of Spool (in cms.)	146	105	86·2	78·5
External Periphery of Spool	180·5	142·5	123·7	119·3
Mean length of one turn (in meters)	163·2	123·8	105	99
No. of Turns per Spool	590	750	865	920
Cross-section of one turn (sq. cms.)	0·11	0·084	0·071	0·072
Res. of one Spool at 60°C	1 73	2·2	2·5	2·5

	A	B	C	D
Res. of all Spools at 60°C	13·8	17·5	20	20
Voltage drop in Rheostat	40	40	40	40
Voltage per Shunt Spool	26·3	26·3	26·3	26·3
Current in Shunt Winding	15·2	12	10·4	10·3
Ampere-turns per Spool	9000	9000	9000	9500
Watts per Spool	400	315	273	270
Cylindrical Surface per Spool in sq. dcm.	42·2	30	25·5	24·5
Watts per sq. dcm.	9·5	10·5	10·6	11
SERIES WINDING.				
Current in Diverter	400	350	300	250
Current in Series Winding	600	650	700	750
Number of Turns of Series winding	2	3	4	5
Cross-section of one Turn (sq. cms.)	5·1	5·1	5·1	5·1
Resistance per Spool at 60°C	0·00013	0·00016	0·00184	0·0002
Watts lost per Spool	54	68	90	110
Watts lost per sq. dcm. of Cylindrical Surface	8	9	10	10·5
LOSSES AND HEATING.				
Armature C^2R loss	3050	4250	5900	7500
Armature Iron loss	6700	4700	3500	2950
Total Armature loss.	9750	8950	9400	10450
Cylindrical Surface of Armature Winding	245	225	235	245
Watts per sq. dcm. of Armature Winding	40	40	40	43
Current density at Brush (amps. per sq. cm.)	6	6	6	6
C^2R loss in Brush Contact	2000	2000	2000	2000
Brush pressure in Kg per sq. cm.	0·1	0·1	0·1	0·1
Friction Coefficient	0·3	0·3	0·3	0·3
Peripheral Speed of Commutator (meters per sec.)	7·9	7·9	10·4	11·8
Friction loss of Brushes per Ampere	·8	·8	1·0	1·15
Total Friction loss of Commutator	810	810	1010	1160
Total Commutator loss	2840	2830	3030	3180
Cylindrical Surface of Commutator (sq. dcm.)	62	62	70	79
Watts per sq. dcm. of Cylindrical Surface	46	46	43	40
EFFICIENCY.				
Iron loss	6700	4700	3500	2950
C^2R loss of Armature	3050	4250	5900	7500
Watts lost at the Brush Contact Resistance	2000	2000	2000	2000
Brush Friction loss	810	810	1010	1160
Friction loss at Bearings	2600	2400	2200	2000
Watts lost in Shunt Winding	3200	2520	2184	2160
Watts lost in Series Winding	430	540	720	880
Watts lost in Shunt Rheostat	610	480	415	410
Watts lost in Series Diverter Rheostat	290	290	300	300
Total of all losses	19700	18000	18300	19400
Output at full load	250000	250000	250000	250000
Input at full load	269700	268000	268300	269400
Commercial Efficiency at full load	93%	93·5%	93·3%	92·9%
Commercial Efficiency at ½ load	88·5%	90·9%	91·5%	91·5%
Constant losses	14900	11020	9380	8720
Variable losses	5800	6980	8920	10685
WEIGHTS IN KGS.				
Armature laminations (including the slot area)	2020	1460	1130	1000
Armature Copper	147	210	290	365
Commutator Segments	275	275	310	350
Magnet Core	2560	1500	1040	850
Yoke	3560	2280	1600	1326
Shunt Copper	750	550	460	460
Series Copper	135	150	170	200
COST OF EFFECTIVE MATERIAL IN SHILLINGS.				
Armature Copper	300	420	580	730
Commutator Copper	550	550	620	700
Spool Copper	1770	1400	1260	1320
Armature laminations	1010	730	560	500
Cast Iron	540	330	240	200
Cast Steel	860	500	350	280
Total Cost of Effective Material	5030	3930	3610	3720

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ROOF BEVELS.

PART I.

By RUFUS E. MARSDEN.

IN selecting the subject of roof bevels for illustration in "Technics," the author has been guided by the fact that the subject proves itself to be of perennial interest to students of carpentry and building construction. It is hoped that the present article will enable any reader to gain an intelligent knowledge of the principles of the subject, sufficient to enable him to put them into practice at the first opportunity.

Before commencing to study an example of roofing, it will be necessary to master two fundamental problems of geometry, upon which the theory of roof bevels rests. Take a piece of clean paper and lay it on the table in a horizontal position. Upon this draw a straight line, as A B (Fig. 1). Place a 60° set square with its shortest edge on this line and the plane of its surface in a position perpendicular to the plane of the paper. To obtain the plan of the set square in this or any other position, it is only necessary to project all points on the set square on to the horizontal plane, by using projectors perpendicular to the latter. The elevation can be obtained by projecting all points on to a vertical plane.

The plan of the set square in a vertical position is shown by *a b* (Fig. 2), while its elevation is *a' c' b'*. An edge view, looking in direction of arrow, is given by *c'' b''*.

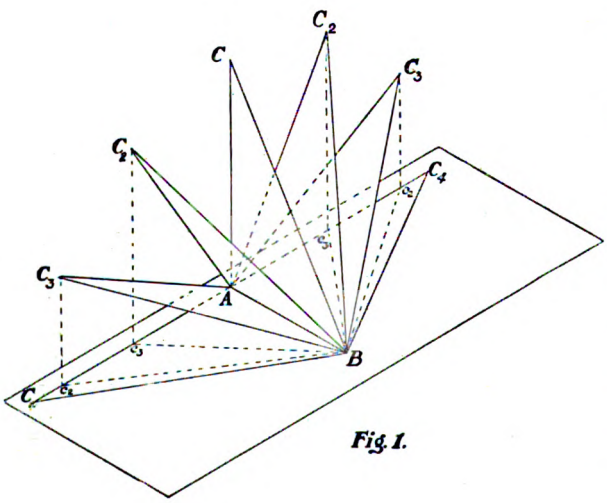

Fig. 1.

Having understood what is meant by plan and elevation of a set square in a vertical position, now rotate the set square down so that the point C (Fig. 1) moves through the positions C_2 C_3 till it comes at last to a position represented by C_4 in the horizontal plane. While C has been made to pass through C_2, and C_3, to C_4, the edge which rests on A B must be kept to this line as if hinged to the paper at A B. If the set square is stopped at various positions, the plan of point C will always be found to fall on a line making an angle of 90° with A B. This happens, on whichever side of the vertical position the set square is inclined. This is illustrated by isometric projection in Fig. 1 and by plan and elevations in Fig. 2, and proves that any point in a plane hinged to a horizontal plane, has a plan which moves at right angles to the hinge whenever the plane containing it is moved. The projection of the plane of the set square is known as the rebattment of the plane; and only when the set square is rebatted into the horizontal plane are we able to see the true shape of its angles and the true lengths of all its sides.

The second problem is to find the angle between two sloping surfaces which meet or intersect.

Let *aa*, *bb*, *cc* (Fig. 3) be the plan and *b' b'*, *c' c'* the elevation of a piece of wood, triangular in section, with ends roughly broken off. Suppose it to be a portion of a fillet given to a carpenter, so that he could make a length similar in section to it. The first thing he requires to do is to determine the true shape of the section: this is best done by placing the specimen "square" before him on the bench hook, and sawing square across it. The saw-cut so made is shown in plan by *d*, *f*, *e*, and in elevation by *e'*, *f'*. When the cut is examined it is found that it lies in a plane perpendicular to the intersection of the two sloping sides, or to the ridge *c c*.

Now suppose the specimen to be hinged along the line *l m* and to be elevated to the position $c_2' c_2'$, $b'_2 b_2'$ the saw cut travelling with it. The plan of the saw cut now becomes $d_2 e_2 f_2$; but as the plane of the saw cut is not parallel to the

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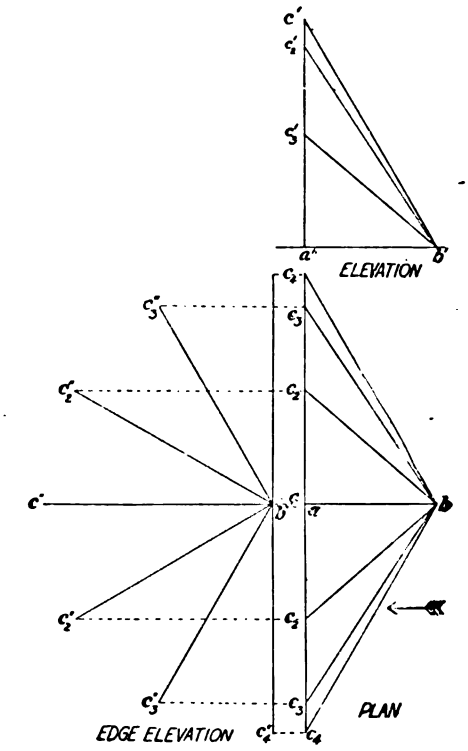

Fig. 2.

horizontal plane, this plan does not give the true shape. It must therefore be rebatted till the point f_2' reaches f''; in this position we get the plan e_2 d_2 F, which gives the true shape of section, and therefore real angle between sides. Thus to get real angle between two sloping surfaces, it is necessary to make a cut in a plane perpendicular to the ridge between them, and find true shape of the section so made.

An isometric projection of what is known as a pavilion roof, having a rectangular plan, is given in Fig. 4. The roof having slopes from sides, as well as from ends, is said to be *hipped*.

From this it is evident that we have to find bevels of the following members :—

(*a*) Common rafters, as H *d*, H *b*.
(*b*) Hip rafters, as E C, E A., etc.
(*c*) Jack rafters, as S *x*.
(*d*) Boarding for roof, as at W.

In Fig. 5 we have the plan of the roof shown by A B C D E F. This plan would do for a roof of any slope: 30° has been selected for the example. A section through the centre of plan is shown in Fig. 5. This is obtained by projecting plan of eaves to *b' d'*, and then drawing lines, making 30° with *b' d'*, from each of these points. This section (Fig. 5) at once gives the bevels for the common rafters as shown at H and *b'*. The application of these bevels to a length of common rafter is shown immediately above this section. A square has been shown, to obtain an upright joint between common rafter and side of wall plate; but it is evident, since this is parallel to joint of rafter to ridge, that the top bevel might have been used instead.

It may as well be here observed, that the drawings shown are too small to obtain the true length of the roofs member from in practice, and that detailed drawings to a larger scale must be used for this purpose; but once the bevels are properly understood, this is easily done. The line H *b'* is the true length of common rafter such as H *b* (Fig. 4), but the thickness of ridge and wall plate is omitted from drawing.

The hip rafter next comes in for treatment. In the roof shown, all hip rafters are equal in length; consequently we can consider any one of them. Take the one starting from the corner A, and of which A E is plan. As the ridge E F is level, it is evident that E is at a height above plane of wall plates equal to H K (Fig. 6); therefore, at right angles to A E set up this height. Then A *e'* is the true length of line A E, and the bevels for hip rafter are shown at A and *e'*. The application of these bevels is given above A *e'*.

As the hip rafter stands at the intersection of the planes representing end and side of roof, it will be seen that it requires planing to an angle on its upper edge, so that half of its upper surface lies in each plane. This is called "backing" the rafter, and to know the proper angle for backing we must find the true angle between side and end of roof.

Taking the rafter C E, find its elevation

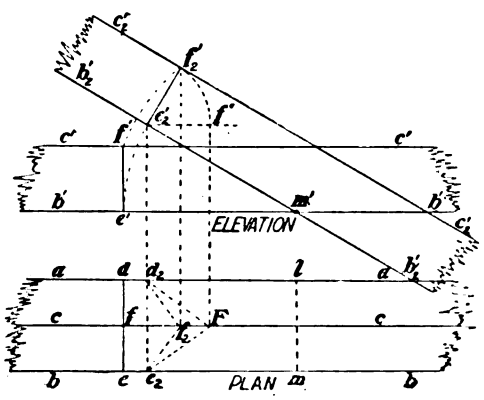

Fig. 3.

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C e'' as before; now draw the elevation of a cut through C e'' perpendicular to it; C e'' being the ridge of our section at present has an unknown angle (compare with Fig. 3). Such a cut is shown by $m'n$, n being point of intersection of m' n with C E. Draw P Q through n at right angles to C E, this being the plan of lower edge of perpendicular cut. Find the true shape of the triangle having P Q for base and apex at m', the plan of m' not being shown. That is, with n as centre and n m' as radius, swing m' down to M. Then P M Q is correct angle for backing of rafter. A section of the hip rafter with backing is shown.

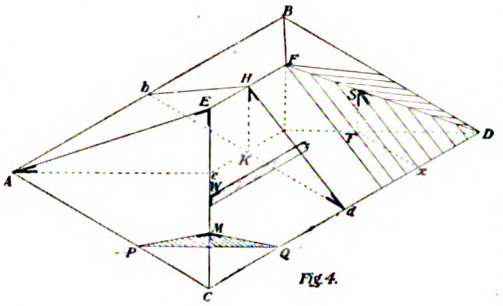

Fig.4.

The boarding may be considered next. To find bevels for the boards, it will only be necessary to find true shape of one side or end, as the sides being of equal inclination, the bevels between lines of boarding and hip rafters are the same. From Fig. 6 we know that the true length of the line E R is H d', so with centre d' and radius d' H swing point H round till it comes to h, this being the elevation of H when plane of side C D E F of roof has been rebatted upon hinge C D on to horizontal plane. The track of E in plan, while the side has rotated, is E E_1. Project from h on to the line E E_1 and it will give E_1 as the position of E when the rebatted side is lying in the horizontal plane. Point F can be found in similar manner. Therefore, C D E_1 F_1 is the true shape, or development of side C D E F. The bevel for cutting the boards to is given at E_1, and it is also shown applied to a board.

If the jack rafters are developed with the side of the roof, the angle between their top edges and the side of the hip rafter will be seen. This is shown at S (Fig. 5). By looking at Fig. 3 it is evident that the down bevel for the jack rafters is the same as that for common rafters. That is, the angle T S x is the same as angle K H d (Fig. 5).

The best way to thoroughly comprehend the subject of roof bevels is to make a small model, working entirely from prepared drawings, of a roof with all its members to scale. Failing this, cardboard models, if well employed, will do much to elucidate any difficulties that may remain after reading this article.

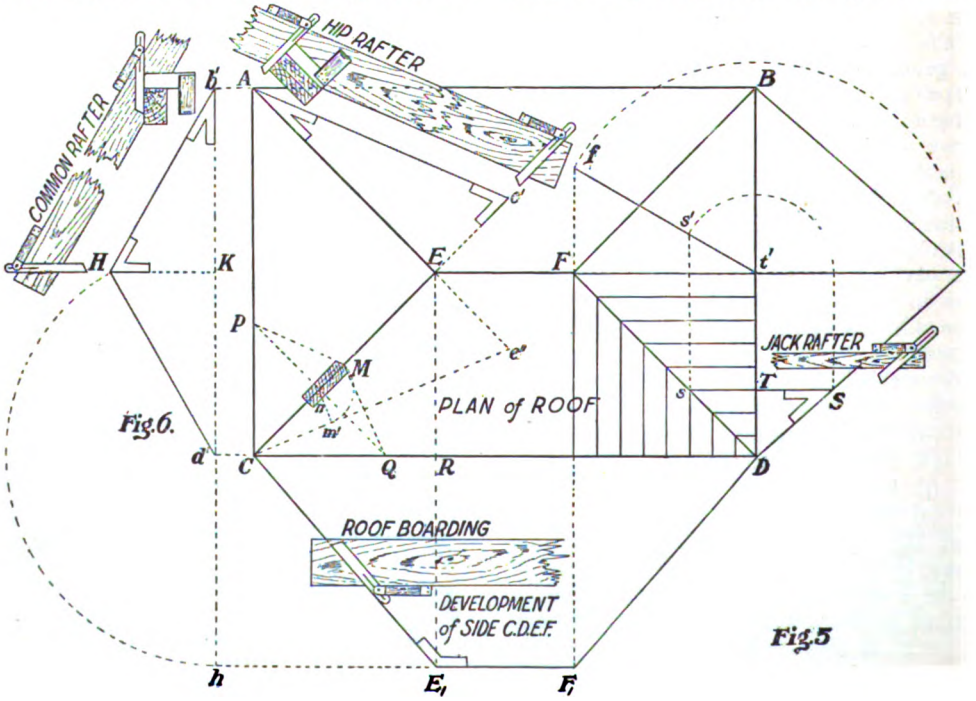

Fig.6.

Fig.5

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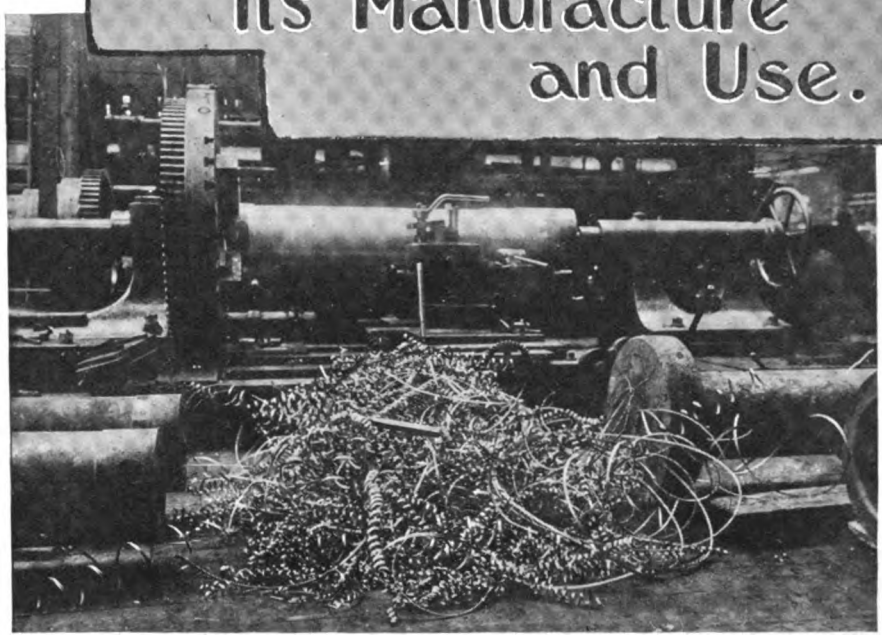
HIGH-SPEED TOOL STEEL
Its Manufacture and Use.



By J. M. GLEDHILL,* of Messrs. Sir W. G. Armstrong, Whitworth & Co., Ltd.

IN treating of this subject—the latest and one of the most startling developments in the art of steel manufacture – it may be instructive to begin by giving a brief account of the manufacture of ordinary cast steel; so that the characteristics of crucible steel, and the extent to which its manufacture differs from that of other classes of steel, may be more readily understood. It may be stated that, besides the crucible process, there are now practically three systems in use—

1. The Open-hearth, or Siemens-Martin;
2. The Bessemer;
3. The Basic Open-hearth.

In the Siemens Open-hearth system, the first experiments carried out on a working scale were made by M. Martin, near Paris, in 1865: the main success of the process was probably due to the adoption of the gas furnaces of the Siemens Brothers. In the Siemens process, cast steel is manufactured by the fusion of pig-iron with various proportions of steel scrap and iron ore, in a regenerative gas furnace fed with producer-gas; this gas is generated by passing a current of air, induced by a steam jet, through red-hot coal. The furnace itself is generally rectangular in shape, with large gas and air chambers under the bath into which the metal is charged and melted. There are gas and air ports at either end of the furnace, and the direction of the gas-flame can be, and is, reversed periodically, generally about every half-hour. The gas and air for combustion are passed through the regenerator chambers, which are filled with bricks, placed therein in such a manner as to form a series of flues or passages. By this regenerative process an intensely high temperature is obtained. Briefly the operation in the Siemens open-hearth is as follows:—

I. Siemens-Martin Process.

Pig-iron is charged into the hearth of the furnace, and melted in presence of oxide of iron in the form of hematite ore. Oxygen

* Paper read before the Coventry Engineering Society, March 4, 1904.

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from the oxide of iron combines with the silicon and carbon in the pig-iron, leaving the molten iron in the furnace to be immediately converted into steel by the addition of Spiegeleisen or Ferro-manganese. This Spiegeleisen is pig-iron containing certain known percentages of carbon and manganese: a proportion added to the molten bath of iron in the Siemens furnace converts that iron into what is called "steel," varying in its percentage of carbon, and therefore in its degree of hardness, according to the amount of spiegel added. If, for example, such a percentage of spiegel has been added as will give 0·5 per cent. of carbon to the bath of iron, the product would be classed in the category of hard steel, *i.e.*, steel which becomes more or less hard when quenched. Mild steel, containing under 0·5 per cent. of carbon, is not sensibly hardened when so treated. After the addition of the spiegel, the steel is ready to be tapped out into one or more ladles, and then run from these into ingot moulds of various shapes and sizes according to requirements. An ingot of 70 to 80 tons or more can be made in a single cast by the Siemens system; it may afterwards be re-heated, and forged or rolled as required.

In concluding this brief reference to Siemens steel, it may be said that its manufacture forms one of the world's principal industrial developments; for, on account of its purity and uniformity, it is utilised for a great variety of purposes in every phase of modern engineering. From it are built our principal means of defence and offence—that is, our battleships, their armour plates, guns, projectiles, and propeller shafting; in addition, it is used for an infinite number of other purposes in engineering construction.

II. Bessemer Process.

This system of steel manufacture, like the Siemens, is associated with the name of its inventor, Sir Henry Bessemer. His first patent was taken out in the year 1865, and after much perseverance and skill in overcoming practical difficulties, the process was perfected on a manufacturing basis in Sheffield.

In the Bessemer process, pig-iron is melted in a cupola, and then transferred into a converter—a sheet-iron vessel lined with siliceous ganister or other highly refractory material. The converter consists of three parts (*i.e.*, the body, the hood and the bottom) which are made separately, of plates which are strongly rivetted together. The body of the converter is generally cylindrical, and to it are fixed trunnions upon which the converter revolves. The trunnions are hollow, and one of them conducts an air-blast through a pipe connected to the bottom of the converter. The base of the converter is a metal plate through which openings are left for the insertion of the tuyeres, which are clay cylinders perforated with a series of holes: beneath these is the air chest into which the air is forced. A rapid stream of air is thus blown by pressure through the molten iron in the converter, and this causes oxidation to rapidly take place, burning out the impurities and removing, after a certain period of the blow, all the carbon and silicon therefrom. Spiegeleisen is then added to the molten metal in the converter, the amount varying with the degree of hardness or temper of steel required, just as in the Siemens process. Then, when the metal is ready, the converter is turned over on its trunnions and the steel is poured from its mouth into ladles for casting into ingots. Although Bessemer steel is used for a great many purposes, it does not rank so high, as regards regularity and quality, as Siemens steel.

III. Basic Processes.

These systems of steel production are carried out on the same lines as the Siemens and Bessemer above described, except that the lining of the furnace or converter, in which the molten metal is decarburised, consists of a basic instead of an acid material.

In the Siemens and Bessemer acid processes, none of the phosphorus in the pig-iron is removed during melting, owing to the acid, *i.e.*, the siliceous nature of the lining used; this prevents the use of pig-iron containing a high percentage of phosphorus. After much thought and experiment, it was ultimately found that, by the adoption of a basic lining, consisting of magnesian limestone and dolomite, certain chemical reactions take place in the molten iron in contact therewith, which eliminate the phosphorus. Thus it became possible to utilise inferior qualities of pig-iron, and dephosphorise them by contact with the basic lining. Basic steel, generally speaking, is less uniform than that made by the acid process, and it is not much used in this country, especially in districts where good hematite pig is obtainable; but where phosphoric ore is prevalent, as on the Continent, it is largely adopted.

IV. Crucible Steel.

We now proceed to a description of the process of crucible steel manufacture. This

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steel is required in our workshops to cut and shape the steel produced by the systems just referred to.

The system of making steel in crucibles is by far the oldest. What is known as "Wootz" steel, produced in India centuries ago, was made by melting small pieces of wrought iron, together with pieces of wood and green leaves, in a crucible made of earth and charcoal. "Wootz" steel, at one time, was imported from India for the manufacture of various cutting tools; and though the system is now almost extinct, it is still carried on in one or two districts to a small extent.

It was in Sheffield that crucible steel was first extensively manufactured, by Benjamin Huntsman, during the year 1750; and it is to his skill that the world is indebted for one of its greatest industries.

Huntsman was originally a watchmaker by trade, and it is said that the difficulties he had with his springs led him to turn his attention to the production of his own steel for them. He made exhaustive trials at Handsworth, near Sheffield, and his steel eventually attained a very high reputation.

Turning now to the present condition of manufacture, it has been proved from long and extensive experience that the finest qualities of crucible steel can only be made by using the best brands of Swedish or Dannemora ores, which, on account of their freedom from impurities—that is, their low percentages of phosphorus and sulphur—are rendered the most suitable for producing tool steels that will best retain their cutting edges. Percentages of phosphorus greater than 0·03 render tool steel worthless. Of course, these Swedish irons are expensive, and the process of converting them into steel is slow and costly, as only comparatively small quantities of steel can be produced for a given expenditure of fuel and labour. It therefore follows that the best brands of crucible steel must always command a high price. Good steel cannot be produced from bad materials, nor can bad steel be made into good steel; but on the other hand, good steel can very easily be converted into bad steel if it is not treated properly. To sum up on these points: if good crucible steel is to be produced, good materials must be used and a fair price paid for the product.

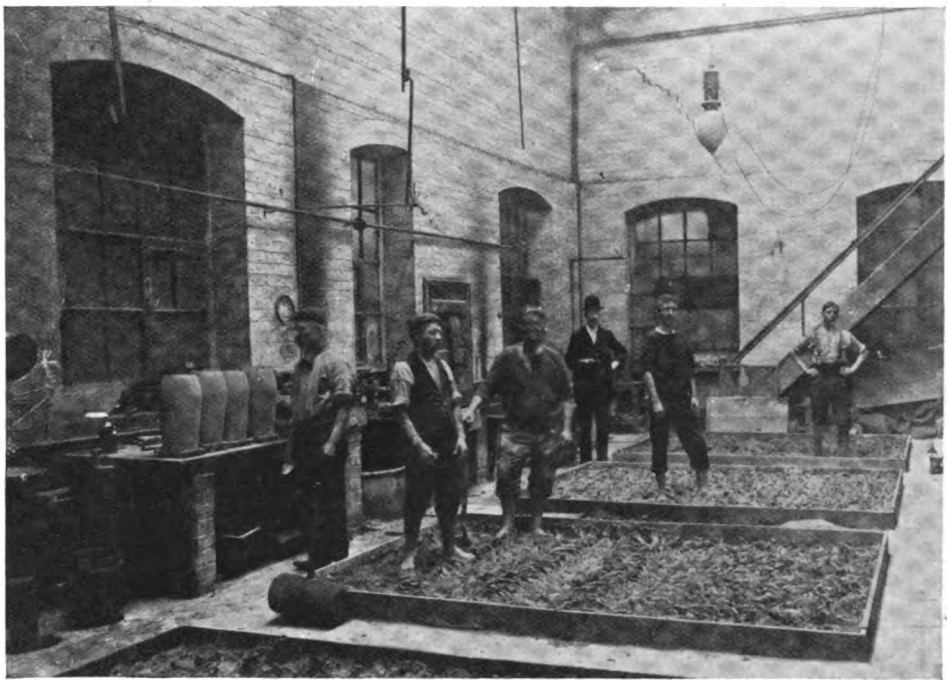

FIG. 1.—VIEW OF THE VARIOUS FIRECLAYS AND COMPOUNDS BEING CAREFULLY WEIGHED, MIXED, AND TRODDEN WITH THE BARE FEET, SO AS TO THOROUGHLY CONSOLIDATE THE MIXTURE AND FREE IT FROM AIR SPACES.

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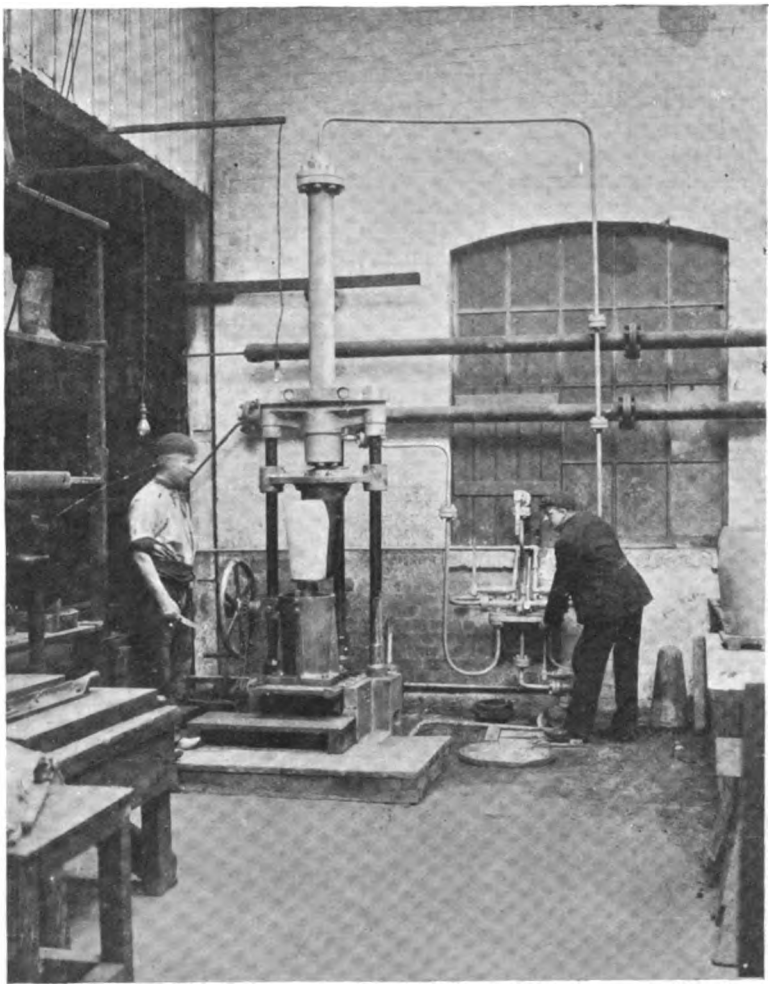

FIG. 2.—CRUCIBLE AFTER BEING PRESSED INTO SHAPE BY HYDRAULIC POWER.

GRADES OF STEEL.

There are several grades or tempers of ordinary crucible steel, each being suited to its own particular class of work. It is usual to speak of these ordinary tempers or grades by numbers, as for example :—

No. 1 *Temper*, containing about 1·30% carbon, is suitable for small turning and planing tools, drills and small cutters; also for tools requiring the sharpest edges, such as razors and surgical instruments. Great care must be taken not to overheat this quality.

No. 2 *Temper*, containing about 1·15% carbon, is suitable for turning, planing, and slotting tools, drills, cutters, reamers and engraving tools.

No. 3 *Temper*, containing about 0·90% carbon, is suitable for large circular cutters, reamers, taps and screwing dies, heavy turning tools, large drills and taps.

No. 4 *Temper*, containing about 0·80% carbon, is suitable for cold chisels, hot setts, small shear blades and large taps.

No. 5 *Temper*, containing about 0·75% carbon, is suitable for screwing dies, cold setts, hammers, swages, minting dies, miners' drills, smiths' tools, punches, and shear blades.

No. 6 *Temper*, containing about 0·65% carbon, is suitable for taps, dies, cup drifts, hammers, and stamping dies.

"*Vita*" *Brand* is a very superior water-hardening steel, specially adapted for finishing brass and steel at high speeds in turret and capstan lathe work, and for turning chilled rolls and very hard materials.

"*Dura*" *Brand* is a special water-hardening steel suitable for ordinary drills, twist drills, small mining tools, brass finishing tools, reamer blades, and wood-working tools.

It is very important to the producer, that users of tool steel should state the purpose for which they require it. For it is obvious from the above that using (say) a No. 5 temper where a No. 1 is required, must be unsatisfactory alike to both parties; and often, in consequence, the steel is alleged to be bad, whereas in reality the steel is good, but has been applied to a purpose for which it was not suited.

It is satisfactory to note, however, that users of steel now attend to this point much more than formerly: improved technical edu-

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cation, and more intimate acquaintance with the manufacture and treatment of steel, have enabled them to discriminate better between the various tempers, and to select these in accordance with their specific requirements.

Before describing the process of manufacturing crucible cast steel, it is perhaps desirable to define briefly some of the substances used in its manufacture, as well as certain technical terms.

Bar Iron, or wrought iron, is cast or pig iron from which most of the carbon has been removed by smelting, by puddling or other processes, and has then been rolled into bars of a section and length suitable for cutting into small pieces for charging into the crucibles.

Blister Steel is bar iron that has been cemented, *i.e.* heated for a long period at a high temperature in a converting furnace, in contact with carbon; the carbon gradually percolates into the bar, which thus becomes carburised. The surfaces of the bars, which were previously smooth, finally become rough and dotted with blisters: the fracture of a converted bar is quite different from that of bar iron, as it has been converted, to a greater or less depth, into steel. As the change goes on from the surface inwards, we may obtain cemented bars of different grades, steeled on their surfaces to varying depths, or steeled throughout.

FIG 3.—MAKING PLUMBAGO CRUCIBLES WITH THE "JOLLY."

The grades of cemented steels usually made are :—

No. 1	containing	1·5%	of carbon.
No. 2	,,	1·25%	,,
No. 3	,,	1·00%	,,
No. 4	,,	0·75%	,,
No. 5	,,	0·625%	,,
No. 6	,,	0·50%	,,

Shear Steel. The process of making this is as follows :—

Five short lengths of blister bar are heated in a hollow coke fire, which, by use of a soft blast, admits of being regulated to a welding temperature. During this time the surfaces

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of the bars are covered with fine clay, applied during the heating to exclude air and prevent oxidation. The bars are then laid one over the other, hammered, and welded together throughout their lengths. The product is known as "single shear" steel. To make "single shear" into what is known as "double shear" steel the bar of "single shear" is broken in the middle, the two pieces laid together, welded a second time, and again drawn to the required shape. By this double operation the steel becomes more homogeneous and of a finer texture. We thus obtain a material having a hard and steely exterior, and yet possessing a soft interior, thus securing both hardness and ductility where required.

Spiegel Iron, or *spiegeleisen** is a combination of iron and manganese in varying proportions.

Crucibles.

The vessel in which the melting is effected is called a "crucible" or "pot," and is mainly composed of plumbago, together with certain other materials. Crucibles are also made from clay, where it is desired that no carbon shall be imparted from the crucible to the steel.

One of the first considerations in the melting of crucible steel, is the necessity of ensuring that the crucibles are of the quality required to withstand the very high temperatures necessary: especially is this the case in the melting of the ingredients of high-speed steels, which require extremely high temperatures for thorough incorporation to occur. This difficulty can only be overcome by taking great care in their manufacture, and by utilising only the finest obtainable qualities of the various materials. As the making of a crucible is an important business, it may be interesting to briefly describe it by the aid of illustrations, which are reproduced from photographs of the crucible department at the works of Messrs. Sir W. G. Armstrong, Whitworth & Co., Ltd., Manchester.

Fig. 1 presents a view of the various fire-clays and compounds being carefully weighed, mixed and trodden with the bare feet and balled, so as to thoroughly consolidate the mixture, and free it from air spaces, thus obtaining the homogeneity required. The compound is then made by hand into crucibles of the desired shapes and sizes. The operation of treading the clay with the bare feet may appear, to the uninitiated, to be a crude one; but mechanical ingenuity has so far failed to provide an equivalent process, trodden clay having been found to be more satisfactory in every way than clay treated mechanically.

Fig. 2 shows a crucible specially designed for the melting of steel, after having been pressed into shape by hydraulic power.

Fig. 3 shows the making of plumbago crucibles with the "Jolly." These crucibles are suitable for melting brass, gun-metal, etc. The crucibles are made in all shapes and sizes according to requirement, and hold from 56lbs. to 500lbs. each.

To manufacture crucibles, including their formation and drying, occupies anything from three to six weeks, according to size; so that the high cost of the plumbago and other materials, combined with the length of time in completion, renders the item of plumbago crucibles an expensive one in crucible steel manufacture. In the case of steel melting, we generally make plumbago crucibles last from eight to ten rounds: that is, they can be used eight to ten times before being cast aside; whilst plumbago crucibles, for melting brass, gun-metal, and other similar alloys, will last as many as 36 to 40 rounds.

Steel Making.

Proceeding, now, to the manufacture of crucible cast-steel, it is necessary to first carefully select the blister or cemented bar according to the temper of steel required. This having been done, the bar is broken into small pieces suitable for charging into the crucibles: about 56lbs. of broken bar are generally charged into each crucible, together with the alloys and other necessary substances for the particular temper desired.

Before the crucible is put into the melting furnace, it requires a preparatory heating. This is carried out in a separate furnace, placed close to the melting furnace, so that the crucible can be transferred to the latter in a heated condition. The object of this is to prevent the too sudden heating of the crucible; for were it placed directly in the melting furnace, it would be liable to fracture. The necessary charges being weighed out, are now ready for putting into the crucibles, and are charged therein through a long funnel or bell-mouth tube. The melting holes are either heated by coke or by means of gas in a regenerative furnace, each division of such a gas furnace holding six or more crucibles. The process of melting occupies anything from 3 to 4½ hours, according to the brand

* Spiegeleisen, from German *spiegeln*, to shine, glitter, and *eisen*, iron.

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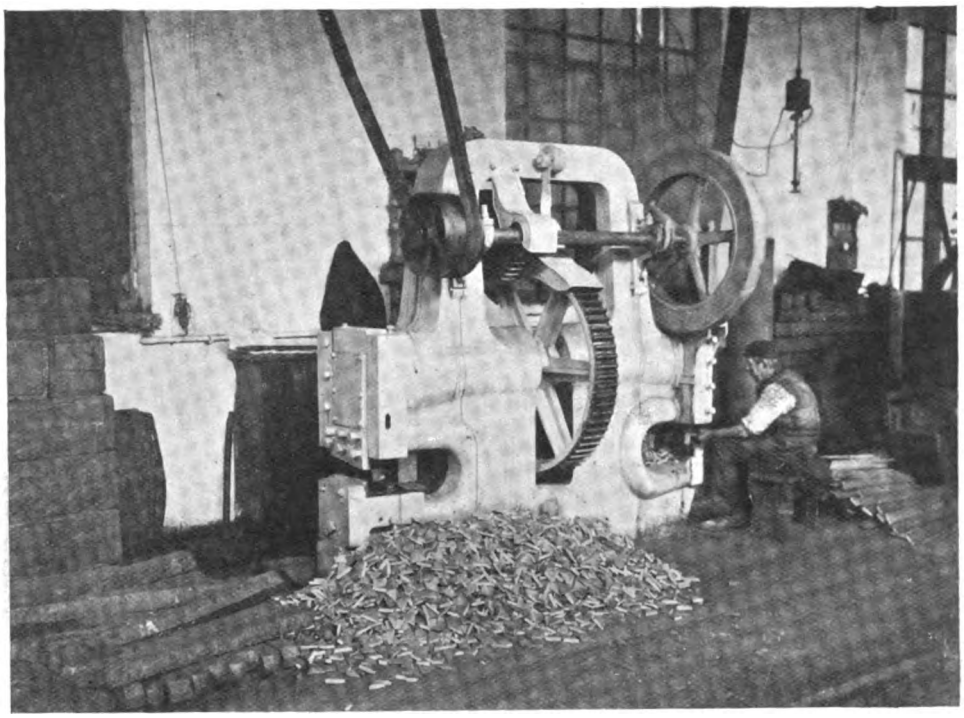

FIG. 4.—VIEW OF A PAIR OF DOUBLE-ACTING SHEARS, ENGAGED IN CUTTING UP THE SWEDISH BAR IRON INTO SMALL PIECES FOR CHARGING INTO THE CRUCIBLES.

of steel being worked—the higher grade brands, such as high-speed steels, taking a longer time to melt and thoroughly mix the various alloys they contain.

The skill of the chemists and leading melters is now brought to bear on the important operation of melting: the temperature of the furnace is regulated by them, the contents of the crucibles being inspected from time to time, so as to decide exactly when they are thoroughly mixed together. It is only from long experience in melting that the correct condition can be ascertained, so as to decide when the steel is properly melted and is just ready for casting into ingot form. The crucible containing the molten steel is withdrawn by a man called a "puller out"; as a preliminary precaution, this man envelops his legs with wrappers saturated with water, so as to prevent his apparel taking fire; but, should this occur, there is every convenience at hand, as a tank is provided close to the pot-holes, into which he can plunge and "extinguish himself."

Fig. 4 shows a pair of double-acting shears engaged in cutting up the Swedish bar iron into small pieces for charging into the crucibles. The bars are carefully watched during shearing, to see that they are quite uniform and free from local defects which would be detrimental to regularity in the quality of the steel.

Blister bar, and Swedish converted bar, being too hard to cut with shears, are broken by hand into pieces similar to those into which the Swedish bar is cut. The pieces are now transferred to the metallurgical department, where the various irons, alloys, ferros, etc., etc., are carefully selected and weighed before being charged into the crucibles in the melting furnace.

It may be interesting to give the costs of some metals used in steel manufacture:—

Vanadium costs	40*s.* 0*d.*	per lb.	or £4,480	per ton.
Molybdenum ,,	6*s.* 0*d.*	,,	or £672	,,
Tungsten ,,	2*s.* 6*d.*	,,	or £280	,,
Nickel ,,	1*s.* 6*d.*	,,	or £168	,,

It will thus be seen that, since large percentages of such alloys are used, high-class crucible tool steel is naturally a costly product.

ALLOYS USED.

A few particulars of some of the alloys used in steel making may be of interest.

1. *Wolfram.*—This is one of the chief ores from which tungsten is extracted. It is

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FIG. 5.—GENERAL VIEW OF TWO SETS OF MELTING FURNACES, USING COKE.

commonly found massive, and associated with tin-stone. The ore is of a dark greyish-black colour, and its structure is lamellar. The specific gravity varies from 7 to 8, and in composition it is a tungstate of iron and manganese. The analysis gives :—

75% to 76% tungstic acid.
9% ,, 10% protoxide of iron.
4% ,, 14% protoxide of manganese.

This mineral is found in Cornwall, France, Styria, and the United States.

2. *Ferro-Vanadium.*—It is only in recent years that use has been made of vanadium in the manufacture of steel. The use and advantage of this element is distinctly seen in the improvement and efficiency it gives to steel, although its present price prohibits its general adoption on any large scale. Minerals containing vanadium are found in Mexico and Sweden. Vanadium is also found associated with lead in Scotland.

3. *Ferro-Silicon.*—This is an alloy of iron containing from 10% to 50% of silicon. Alloys containing from 10% to 18% silicon are made in the blast furnace by the reduction of highly siliceous iron ores, using a very hot blast. The highly siliceous ores are imported from Spain. The finer grades (those containing from 25% to 50%) are made in the electric furnace. The higher percentage alloys are spongy and very friable.

4. *Metallic-Chromium.*—The fracture of this metal is very lustrous, and keeps for a long time without tarnishing. The metal is prepared in the electric furnace.

5. *Metallic-Manganese.* — The fracture is very lustrous, but readily tarnishes in the air. Specimens prepared in the electric furnace and containing only a trace of carbon, are very convenient for making steels high in manganese and low in carbon.

6. *Ferro-Molybdenum.*—One of the chief sources of molybdenum is molybdenite, which is sulphide of molybdenum, and resembles graphite in appearance. Its composition is :—

57% to 59% molybdenum.
39% to 40% sulphur.

Molybdic acid is prepared from this mineral, and, after mixing with charcoal, is subjected to a high temperature in a covered crucible and reduced to molybdenum powder. This is mixed with iron and charcoal and melted in crucibles to obtain ferro-molybdenum alloy.

7. *Ferro-Tungsten.*—This is a rich alloy of iron and tungsten. It is prepared by melting together Swedish bar iron, tungsten powder and charcoal. Other varieties contain from 45% tungsten. Such alloys are intensely hard and very difficult to break.

8. *Tungsten Powder.*—This is a metallic powder, varying in colour from grey to black.

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The specific gravity is very high, *viz.*, 19·4. The wolfram ore is crushed and concentrated, and then infused with alkali carbonates whereby the tungstic acid is converted into a tungstate of soda. This is soluble in water, and so can be separated from the insoluble oxides of iron and manganese. Tungstic acid, as a yellow precipitate, is obtained by the judicious addition of mineral acid to the solution of tungstate of soda. The tungstic acid is separated, dried, and, after mixing with charcoal powder, is subjected to a high temperature in a covered crucible; the tungstic oxide being thereby reduced to metallic tungsten. Tungsten has the property of imparting intense hardness to steel, especially when associated with chromium and manganese.

9. *Nickel.*—This is another important element used as an alloy with steel; it increases the elastic limit and breaking stress, whilst adding toughness and maintaining ductility.

Nickel ore is found associated with arsenic, copper, iron, and cobalt, and is obtained in large quantities from North America. Small quantities are also found in the British Isles. The most recent process of producing nickel is by the "Mond" process, which consists in passing carbon monoxide over the nickel ore heated to a definite temperature, whereby the nickel combines to form nickel carbonyl. At a higher temperature this carbonyl dissociates and deposits nickel; the carbon monoxide passes off and is used again. Thus the process is a continuous one.

10. *Ferro-manganese and Spiegeleisen.*—These alloys are usually divided into two grades: one containing 16% to 20% manganese, is called spiegeleisen because of its bright appearance; the other variety, containing from 75% to 85% manganese, falls under the name of ferro-manganese. The alloys are made by smelting manganese ores with coke and limestone in the blast furnace. About 30% of the manganese in the charge is lost in the slag or carried off by the waste gases. Composition:—

Spiegel.....	C. 5%	O.Fe. 74%	Mn. 20%
Fe Mang. .	C. 7%	O.Fe. 12%	Mn. 8c%

Manganese ores are imported from Chili, Brazil, and Japan.

11. *Ferro-Chrome.*—This is a rich alloy of iron with chromium, varying in its percentage of chrome from 60% to 80%. Its price varies from £30 to £120 per ton, according to grade. These grades are based on the percentage of carbon: the lower percentages of carbon being the purest and most costly. The carbon varies from 1% to 10%. The commercial source of these alloys is chrome iron ore; alloys containing up to 40% chromium are made in the blast-furnace. The chrome iron ores are found in Shetland, France, Silesia, Bohemia, Norway, Asia Minor, and North America. The higher percentages and finest qualities are now made in the electric-furnace. The use of chromium in steel is very general, including armour plates, tool steel, projectiles, etc.

Melting Furnaces.

Fig. 5 gives a general view of two sets of melting-furnaces, the fuel being coke. The crucibles are stacked on the shelves before being placed in the furnaces. On the left-hand side is a 24-pot furnace being charged with the mixing received from the weighing-room; each crucible, of course, being charged separately. The men may be seen stripping the moulds from, and "topping" the ingots. By "topping" is meant the breaking off of the ingot-top, so as to reveal the fracture of the steel: by which the expert can tell whether the melting has been good or bad, and the ingot fit for passing forward to the metallurgical testing department.

The ingots are carefully looked over in the melting department to see that they are quite sound and free from outward defects. The old rule of thumb method of judging the different tempers purely by fracture has been replaced by the more scientific way, *viz.*:—chemical analysis. The whole of the ingots are tested by metallurgical chemists to prove absolutely that their constitution is correct and suitable for the purpose required; they are then marked in their respective brands and stacked in the ingot warehouse.

(*To be continued.*)

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CHARACTERISTIC COTTON FIBRES.

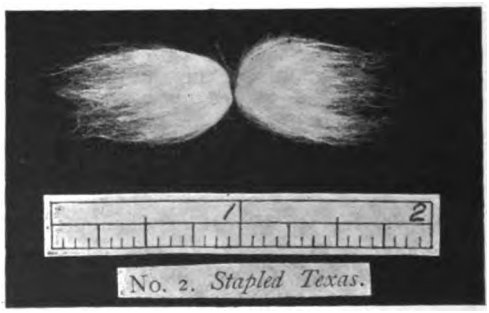
By J. H. DAWSON.

TO acquire a good up-to-date knowledge of the names and characteristics of the various cottons now upon the market, is one of the ideals that cotton spinners should aim at. The text-books of a decade ago were undoubtedly very useful at the time, and the descriptions of the many classes and varieties of cotton which they gave were then of great assistance. Many changes, however, have since taken place in the methods of cultivation, etc., in the countries and states which were then growing an inferior cotton; consequently the description of their produce ten years ago is not true to-day. On the other hand, a few of the districts noted for good growths at that time do not deserve the same praise now. Several new varieties have also been placed upon the market, so that, take it altogether, a brief description and illustration of the various cottons now offering on the Liverpool market will be useful and instructive.

The botanical names by which the different species (or at least the principal ones) are known are as follows: Sea Island cotton, *Gossypium Barbadense;* South American cotton, *G. Peruvianum;* Egyptian and East Indian cottons, *G. Herbaceum;* and the well-known and much-used (and abused) North American cotton, *G. Hirsutum.*

The names I give in this article are the "local" names, and the names by which the cottons are known on the market; they are, therefore, the names most important for a student of spinning to be acquainted with. A large amount of trouble has been taken by Messrs. R. and C. Gill, cotton brokers, of Liverpool, in obtaining, specially for me, the samples with which to illustrate this article, and I take this opportunity of thanking them. It must be understood, however, that although the samples are very good specimens of the various types, there are many grades of each, and therefore samples of some of them may be got very much worse, and some perhaps better.

No. 1. *Surat.*—A light brown, hard-pressed cotton. Length of staple $\frac{6}{8}$ths to $\frac{7}{8}$ths of an inch, rather lossy in working. Some lots are bright. Suitable for coarse wefts. Works best when used as a mixture.



No. 2. *Stapled Texas.*—A creamy-looking and bright cotton. Length of staple anywhere between 1 in. and $1\frac{3}{8}$ in.; rather leafy in some instances, but the leaf will easily clean out. It is becoming very popular as a twist cotton for counts up to 36's—40's.

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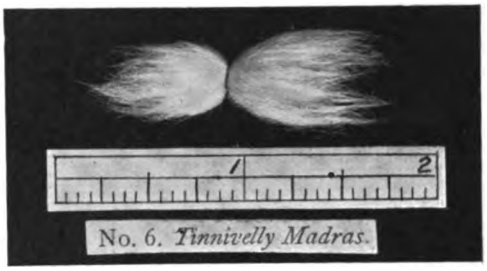
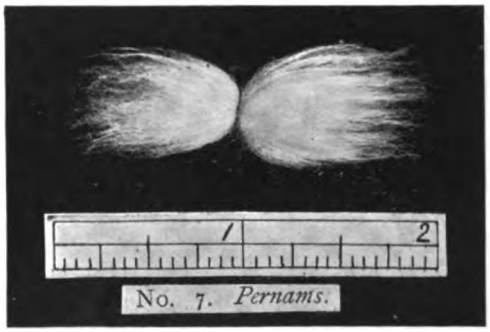
No. 3. *China Cotton.*—A clean and bright cotton, harsh to the feel, length $\frac{3}{4}$ in. to 1 in.; will not lose much in working, but would mix better with short stapled South American than with any other cotton. It is too short for twist, and too hard for weft.

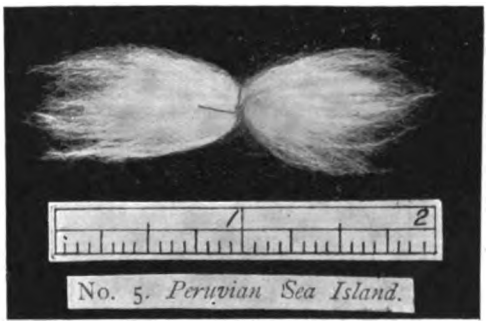


No. 6. *Tinnivelly Madras*, commonly called "Tinnies." A light brown, fairly fine stapled cotton, rather bright-looking. It is a better cotton than No. 1; it is cleaner and longer in staple.

No. 4. *Extra Benders.*—Sometimes called "Extras," "Heavy Benders," etc. A bright, strong and regular cotton, very suitable and much used for twist yarns up to 60's. It is the typical North American stapled cotton. It is not as long generally as long stapled Orleans, but it is much more regular and trustworthy. It is, however, finding a strong rival in "Stapled Texas."



No. 7. *Pernams.*—A South American cotton, bright and clean in appearance, light cream colour, not as soft as the North American breeds, nor as wiry as the typical Peruvian. Would mix well with stapled Texas or heavy benders to make strong twist yarns.



No. 5. *Peruvian Sea Island.*—A bright, creamy, long-stapled cotton, very fine and silky, clean and regular in staple, but inclined to be curly in bulk

No. 8. "*Abasse*" *Egyptian.*—A clean, bright and "meaty" cotton, fine and long in staple, inclined to be white. Would spin either twist yarns or very fine wefts.

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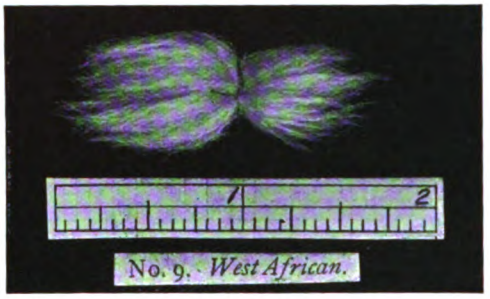


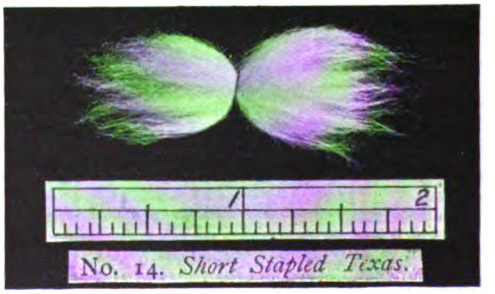
No. 9. *West African.*—A dull yellow cotton, moderately clean, staple ¾ in. to 1 in., rather harsh and wiry. Would spin into coarse twist yarns, or would make strong coarse wefts where colour and pliability are of secondary importance.

No. 10. *Florida Sea Island.*—The finest and best cotton grown (in quantity). It has a very long and regular, fine and silky staple. It is clean and well-ginned, whitish in colour, and spins into the finest known counts of twist. It is mostly used for sewing threads.

No. 11. *Boweds.*—The typical and popular weft cotton for medium-fine wefts; also the lower grades for coarse wefts, either alone or mixed with the East Indians. It has a fine, soft and pliable staple, ¾ in. to 1¼ in. long. The colour varies—almost any shade can be got, from dead white to deep cream or light brown.

No. 12. *Long Stapled Orleans.*—This cotton had a big name a few years ago, but latterly it has become rather treacherous. It is now usually very irregular in length of staple, and consequently causes trouble in working. Its staple is fine and silky, and is generally well matured, therefore being well suited for medium twist yarns. The principal fault (and it is a very serious one) is the afore-mentioned.

No. 13. *Brown Egyptian.*—As its name implies, the colour is brownish. It is very fine and silky in staple, very regular in its convolutions or twistings, and therefore suited well for making strong and closely twisted yarns. It is much used for mercerising purposes. Its worst fault is the presence of a certain proportion of short fibres, which have to be removed by combing. This cotton will spin well between 70's and 130's.



No. 14. *Short Stapled Texas.*—A bright creamy cotton which is used as a substitute

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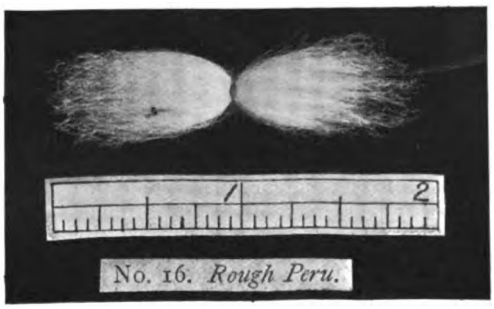
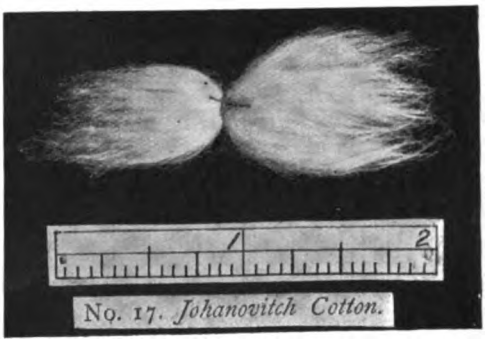
for Boweds when the latter are scarce. Some lots are rather harsh, others are much softer. All lots are strong, and weft from these cottons spin and weave well, although they do not "mill up" as satisfactorily as "Boweds." The leaf in these cottons cleans out easily.

No. 15. *Colonial Sea Island* (from Barbadoes).—A fine, long, silky staple, very regular and clean. Like most Sea Islands, it inclines to curl a little in bulk, owing to the great length, and the number of twistings in the individual fibres. The capabilities of this cotton are equal to those of any other cotton grown.



No. 16. *Rough Peru.*—A South American cotton sometimes called vegetable wove. It is very clean, but harsh and wiry in staple. It is used principally as a mixture with wool, and in the hosiery trade of the Nottingham district.

No. 17. *Johanovitch Cotton.*—This cotton, like the "Abasse cotton," is grown in Egypt. They have both been cultivated from "freak' plants found growing amongst the ordinary crop from Egyptian seed. Their individual peculiarities have been fostered, and hence



they are now almost distinct varieties. "Johanovitch" has a fine, silky, very strong staple. It is a rather deep creamy colour. It should spin anything that ordinary Egyptian spins, and much that Sea Island will.

No. 18. *Smooth Peru.*—A companion cotton to Rough Peru, but much softer in staple. It is, however, not quite so clean, but can be adapted to a much wider variety of work than the rough species, simply because its softer nature will allow of its admixture with the North American cottons.

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THEORY OF STRUCTURAL DESIGN.

PART VI.

By E. FIANDER ETCHELLS, A.M.I.Mech.E.

MOMENTS OF RESISTANCE AND SECTION MODULI.

IN last month's issue it was shown that the moment of resistance of a rectangular beam, of breadth b, and depth d, is equal to $\frac{1}{12} b d^3 p$; where p = the tensile or compressive stress at unit distance from the neutral axis.

In practice the engineer does not concern himself with the stress at this, or any other intermediate distance, so long as he knows that the greatest possible stress on the extreme fibres will be within safe limits.

Therefore, p is always expressed in terms of f and y; where y = the distance of the neutral axis from the extreme fibres, and f = the maximum safe stress on those fibres.

By simple proportion, we have

$$\frac{p}{f} = \frac{1 \text{ inch}}{y \text{ inches}},$$

$$\therefore p = \frac{f}{y}.$$

Instead of $\frac{1}{12} bd^3p$ we now have the equivalent

$$\frac{1}{12} b d^3 \frac{f}{y} \quad \text{(Eqn. No. XII.)}$$

To find y, we must discover the position of the neutral axis. It can be proved, but it is here only postulated, that *the neutral axis passes through the centroid of the cross-sectional area of the beam.* An area has, of course, no thickness, no density, no mass, no inertia, and no weight, and, therefore, no centre of gravity; or I might have said that the neutral axis passes through the centre of gravity of the cross section.

Assume that the loading and reactions are vertical; then the neutral axis is always horizontal, no matter how the beam may be turned about its own longitudinal axis.

The examples illustrated in Fig. 36 may perhaps render my meaning clearer. In each of the different positions in which the T beam may be placed, the neutral axis is horizontal, and passes through the centroid of the cross-section chosen. In general terms: the neutral axis of a beam is normal to the plane of loading, and passes through the centroid of the section.

For vertical loads on the beams shown in Fig. 37, the neutral axis is midway between the upper and lower points; therefore $y = \frac{d}{2}$ where d = extreme depth.

An inspection of Fig. 37 will convince the reader that

$$\frac{1}{12} b d^3 \frac{f}{y} = \frac{1}{12} b d^3 f \div \frac{d}{2}$$

$$\therefore \frac{1}{12} b d^3 \frac{f}{y} = \frac{1}{6} b d^2 f \quad \text{(Eqn. XIII.)}$$

Equation XIII is the simplest form of the equation for the moment of resistance of a beam of rectangular cross section. The factor f depends upon the quality and nature of the material, and is sometimes called the *strength modulus.* The quantity $\frac{1}{6} b d^2$ is dependent upon the shape and size of the sectional area and is called the *section modulus* of that particular beam.

In general terms the section modulus equals the "geometrical moment of inertia" divided by the distance between the neutral axis and the extreme fibres; or if Z = section modulus, then $Z = I/y$ where I = the "geometrical moment of inertia."

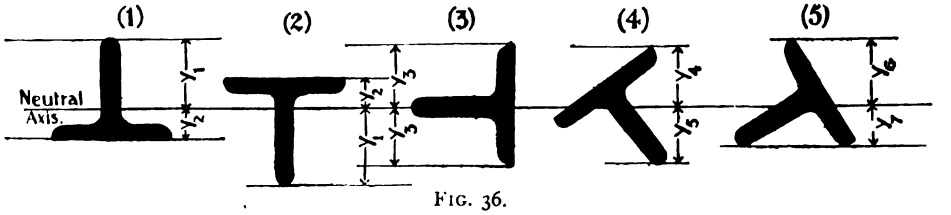

FIG. 36.

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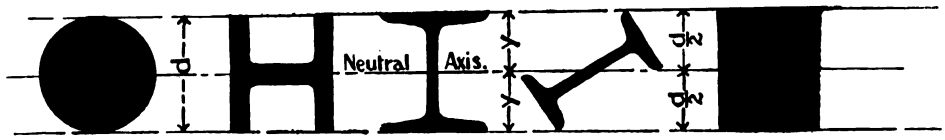

FIG. 37.

In the case of an unsymmetrical section, there may be a greater and a less value of y, as in cases 1, 2, 4, and 5 in Fig. 36. There will consequently be two values of I/y for each position of the T beam. The smaller of the two values is the one usually given in the steel-maker's section book.

For an ordinary rectangular beam of any material, the two values of y are equal, and the equation to the moment of resistance (M R) may be written in any of the following alternative forms.

$$\text{M R} = \tfrac{1}{12}\, b\, d^3 \,.\, p \quad \ldots\ldots (1)$$

$$= \tfrac{1}{12}\, b\, d^3 \,.\, \frac{f}{y} \quad \ldots\ldots (2)$$

$$= \text{I} \,.\, p \quad \ldots\ldots (3)$$

$$= I \,.\, \frac{f}{y} \quad \ldots\ldots (4)$$

$$= \text{Z} \,.\, f \quad \ldots\ldots (5)$$

$$= \tfrac{1}{6}\, b\, d^2 \,.\, f \quad \ldots\ldots (6)$$

Forms 3, 4 and 5 are true for beams of any shape whatsoever, if the value of I or Z for the corresponding shape of section be taken.

For instance, for a round bar of diameter D,

$$\text{I} = \frac{\pi}{64}\,\text{D}^4, \quad \textit{not} \quad \tfrac{1}{12}\, b\, d^3$$

and

$$\text{Z} = \frac{\pi}{32}\,\text{D}^3, \quad \textit{not} \quad \tfrac{1}{6}\, b\, d^2$$

In the better class of steel trade catalogues, the values of the requisite geometrical constants are given, and the problem of finding a beam of the requisite strength resolves itself into looking through the book for a beam with the requisite section modulus. As beams with free ends, and carrying distributed loads, are perhaps most frequently required, I submit one or two time-saving rules of a very simple character.

Let W = the uniformly distributed load in tons.
„ L = the span in feet.
„ l = the span in inches = 12 L.
„ f = the strength modulus = 7 tons per square inch for mild steel.

Since bending moment = moment of resistance to bending,

$$\frac{\text{W}\, l}{8} = \frac{\text{W}}{8} \,.\, 12\,\text{L} = \text{Z} \,.\, f. \quad \text{(Eqn. XIV.)}$$

$$\therefore \frac{\text{W}}{8} \,.\, \frac{12\,\text{L}}{f} = \text{Z}.$$

Therefore for a mild steel beam of any shape,

$$\text{Z} = \frac{\text{W}}{8}\,\frac{12\,\text{L}}{7}$$

$$= \frac{12}{56}\,\text{W L}$$

$$\frac{\text{W L}}{4{\cdot}67} = \text{Z}. \quad \text{(Eqn. XV.)}$$

If we divide both sides of Eqn. XV by L, and multiply both sides by 4·67, we obtain

$$\text{W} = 4{\cdot}67\,\frac{\text{Z}}{\text{L}}. \quad \text{(Eqn. XVI.}$$

Equation No. XVI is very useful if we want to know what load we can put on any given beam.

For an example of the use of Equation XV., let us find what joist will carry a distributed load of 30 tons across an effective span of 14 feet. By Equation XV.

$$\text{Z} = \frac{\text{W L}}{4{\cdot}67} = \frac{30 \times 14}{4{\cdot}67} = 89{\cdot}93.$$

On account of deflection, the depth of the joist must not be less than $\frac{1}{20}$ of the span; therefore the minimum depth must be not less than $\frac{14 \times 12}{20} = 8{\cdot}4$ inches; say 9 inches.

We must now look at the section moduli of all sections 9 inches deep and over, to find what section has a modulus of about 90. The nearest is the 16 inches by 6 inches rolled steel joist at 62 lbs. per foot run, and this has a modulus of 89·99. This will be satisfactory so far as the bending stresses are concerned.

Let us now try to obtain a simple rule which will enable us to find the maximum safe load we may place on any given floor supported by steel joists.

Let w_c = the total floor load, including weight of floor, in cwts. per sq. foot.

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Let B = the distance between the centres of floor joists, in feet.
„ A = area of floor supported by each joist.
= B. L. (square feet).
„ W = total load in tons.

Let all other lettering be same as for previous equations.

$$W = \frac{w_c \,.\, B.\ L.}{20} \quad \text{(Eqn. XV.}$$

$$\frac{W\,l}{8} = Z\,.\,f.$$

$$\frac{w_c\,B\,L}{20}\,.\,\frac{l}{8} = Z\,.\,f$$

$$\frac{w_c\,B\,L}{20} \times \frac{12\,L}{8} = Z\,.\,f$$

$$w_c = \frac{Z\,.\,f}{B\,.\,L^2}\,.\,\frac{20 \times 8}{12}.$$

Since for mild steel joists $f = 7$ tons per square inch,

$$w_c = \frac{Z}{B\,L^2} \times \frac{7 \times 20 \times 8}{12}$$

$$w_c = \frac{Z}{B\,L^2} \times \frac{280}{3}$$

$$w_c = 93{\cdot}3\,\frac{Z}{B\,L^2}. \quad \text{(Eqn. XVIII.)}$$

Of course the weight of the floor per square foot must be deducted from w_c to find the net superimposed load. If we multiply both sides of Eqn. XVIII. by B, and divide both sides by w_c, we obtain

$$B = \frac{93{\cdot}3\,Z}{w_c\,.\,L^2}. \quad \text{(Eqn. XIX.)}$$

This will enable us to find the correct distance apart for any given floor joists; since the span and section modulus, etc., will be known.

Unfortunately, there is no unanimity of opinion as to the best terminology for the various mathematical constants employed in this subject.

The quantity, $\frac{I}{y}$, which I have referred to as the sectional modulus, is in one or two books called the " moment of resistance." Thus the descriptive and rational term *section modulus* is discarded.

The term *moment of resistance* is then applied to a quantity which is not the " moment of resistance to bending," and we are left without a term for that quantity which is equal in magnitude to the bending moment.

The term "resistance" when applied to $\frac{I}{y}$ is not much better. It lacks descriptiveness: it gives no obvious indication as to whether it is dependent upon the nature of the material, or upon the shape and size of the beam.

Before taking up the section moduli of complex sections, I purpose giving a few simple rules for wooden beams.

Let W_c = the total uniformly distributed load in cwts.
f = the strength modulus, or maximum working stress in cwts. per square inch.
Other lettering as before.

$$\frac{W_c\,l}{8} = \tfrac{1}{6}\,b\,d^2\,.\,f. \quad \text{(Eqn. XX.)}$$

$$\frac{W_c \times 12\,L}{8} = \tfrac{1}{6}\,b\,d^2\,.\,f. \quad \text{(cwt. — ins.)}$$

If we divide both sides of this equation by 12 L, and multiply both sides by 8, we obtain

$$W_c = \frac{8\,.\,b\,.\,d^2\,.\,f}{6 \times 12\,L}$$

For Northern pine f may be taken at 12 cwts. per square inch. Inserting the value of f and cancelling, we obtain

$$W_c = \tfrac{4}{3}\,\frac{b\,d^2}{L} \quad \text{(Eqn. XXI.)}$$

The maximum safe central concentrated load can be shown by similar reasoning to be

$$= \tfrac{2}{3}\,\frac{b\,.\,d^2}{L} \quad \text{(Eqn. XXII.)}$$

To find the maximum safe intensity of a floor load, supported by Northern pine or fir joists, we have

$$W_c = w_c\,B\,L$$

Substituting this value in Eqn. XXI., we have

$$w_c\,B\,.\,L = \tfrac{4}{3}\,\frac{b\,d^2}{L}$$

$$w_c = \tfrac{4}{3}\,\frac{b\,d^2}{B\,L^2} \quad \text{(Eqn. XXIII.)}$$

From Eqn. XXIII it can easily be proved that

$$B = \tfrac{4}{3}\,\frac{b\,d^2}{w_c\,L^2} \quad \text{(Eqn. XXIV.)}$$

It will generally be found more advantageous to rely upon judgment and experience in determining the breadth and depth of a beam for any given span, using Equation XXIV. afterwards to fix the correct pitch or distance apart.

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This method will prevent us from designing beams with stresses exquisitely balanced, but nevertheless, of dimensions unknown in the best stocked store. After all, has it not been written, that "when designing, the engineer uses about one part of calculation to six of judgment." Of course the "one part of calculation" is very essential, and cannot be omitted. We can make good lime concrete with one part of lime and six parts of gravel; but we cannot do without the one part of lime.

(To be continued.)

CITY AND GUILDS EXAMINATION QUESTIONS (1904).

Electric Lighting and Power Transmission, Ordinary Grade.

1. On a 200-volt circuit, the current passing through a "bank" of lamps is found to be 12 amperes, but, on inserting a length of cable in series with the lamps, the voltage across the lamp terminals is found to be 195. Suppose that it is permissible to earth the circuit for a short period, how could you test the ohmic resistance of a lightning conductor within easy access of this lighting circuit? Give diagrammatic sketches illustrating your answer.

From the observation of the voltage across the lamp terminals when connected in series with the cable, the resistance of the latter can be determined. The resistance of the "bank" of lamps is obviously equal to

$$\frac{200}{12} = 16{\cdot}67 \text{ ohms (nearly.)}$$

When the cable is inserted in series with the lamps, the P.D. across the ends of the cable is 5 volts, whilst that across the "bank" of lamps is 195 volts. Thus the resistance of the cable is equal to

$$\frac{5}{195} \times 16{\cdot}67 = 0{\cdot}427 \text{ ohm.}$$

To find the resistance of the lightning conductor, connect one main A to earth (Fig. 1), and connect the other main to the upper extremity of the lightning conductor through the bank of lamps L and the cable C. Connect the voltmeter V across the bank of lamps, and thus determine the drop of potential in the lamps. The resistance of the cable and lightning conductor can then be calculated in the way previously used to determine the resistance of the cable; subtracting the resistance of the cable, the resistance of the lightning conductor is found. A source of error lies in the fact that the resistance of the bank of lamps depends on the temperature of the lamp filaments, and therefore on the current flowing through the lamps. If the earthed end of the lightning conductor is merely buried in damp soil, there might possibly be a back E.M.F. due to chemical action, and this would throw the result out of truth; this source of error would be avoided if the system were an alternating current one.

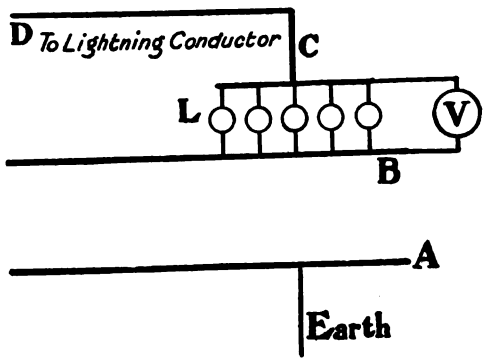

FIG. 1.

2. Describe, with sketches, any arrangement with which you are acquainted for preventing an alternator being switched on the bus-bars with its field unexcited, and discuss the advantages and disadvantages of the device.

Raworth's switch pillar, patented in 1894 and made by the Brush Company, comprises a good example of such an arrangement. Referring to Fig. 2 (in which all the switches are in the "off" position) A, E, and S are discs mounted upon the respective spindles of the devices used for operating the *main alternator*, *field*, and *synchronising* switches. Owing to their configuration, they interlock with each other in such a manner as to make it impossible to close A without having previously closed E and S. In like manner, E and S cannot be opened until A is in the "off" position. This gear

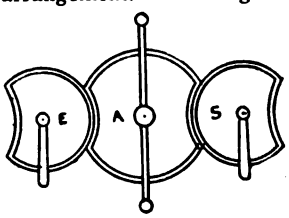

FIG. 2.

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itself is simple and trustworthy; but taking the switch pillar as a whole, it was too complicated. The advantage is, of course, that it is physically impossible to cause damage by operating the switches in improper sequence, but this is all that can be claimed for it. Modern practice tends towards the simplification of switch gear, it having been found better to trust to the common sense and experience of the operator, rather than to automatic and interlocking arrangements.

3. What is the object of electrically interconnecting the several parts of the metallic containing system of an electrical installation, and connecting the whole to earth? What would guide you as to the cross-section of the "earthing" cable in any given case?

The object of electrically interconnecting the metal tubes carrying the cables of an electric circuit, is to maintain the different portions of the tubing at the same potential. This may be necessary in some cases, since the tubes, although connected mechanically, do not make good electrical connection at the joints. If the tubes were joined by being screwed into one another, good electrical connections would be secured; but with some systems of conduits the tubes fit into one another more or less loosely, and the joints are consequently more or less imperfect electrically. Whilst metal tubes are employed to protect and support the cables, and are satisfactory for such uses, it is important that they should not become charged to a potential higher than that of the earth, which would be the case if the insulation of the live cable became impaired and contact be made between the conductor and tube; for then they would become a source of danger. If the separate portions be interconnected electrically and the whole be *perfectly earthed*, the metallic tubing would have the same potential as the earth, and they would not then be dangerous. If the insulation of the cable broke down to such an extent as to produce a large leakage current, the fuse would probably be blown, and thus indicate the existence of the fault. To perfectly earth the tubes, it is necessary to interpose extremely low resistance connections, so that with a fairly large leakage current there cannot be an appreciable difference of potential between the tube and the earth; consequently the cross-section of the earthing cable must be comparatively large.

4. The armature of a direct-current motor has an earth on it; describe fully how you would proceed to locate the fault, giving diagrams of connections for all the tests applied.

There is only one test necessary for locating an earth in the armature of a direct-current motor or dynamo, and this may be carried out as follows:—

Disconnect the field magnet winding and close the circuit with a galvanometer (say) of the ordinary Post Office type, as shown in Fig. 3. Rock the brushes backwards approximately to the position shown, raise one, and connect the other to a few accumulator cells earthed on the other pole. On closing the circuit, a current will flow through the armature winding to earth, inducing a magnetic field in the armature, and of course, a momentary current in the field winding, which will cause a throw of the galvanometer. Turn the armature round, making and breaking the circuit as each

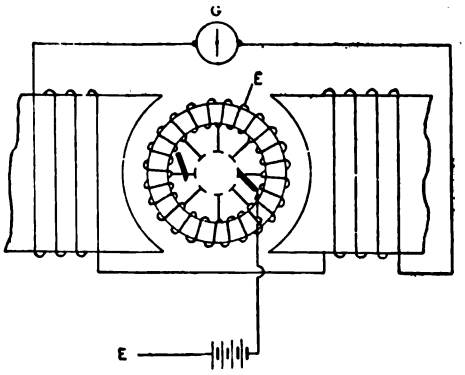


FIG. 3.

commutator segment comes under the brush, and it will be found that when the faulty coil is reached the galvanometer will show little or no deflection, according to its sensitiveness, and the amount of current passed through the armature; when the armature is in this position, the earth cuts out the winding, with the consequence that no magnetic field is generated, and, therefore, no current is induced in the field circuit. The object of rocking the brushes back is to get the consequent armature poles in the centre of the field, thus shortening the magnetic circuit, and enhancing the effect on the galvanometer. This test is applicable to all kinds of direct-current armature windings.

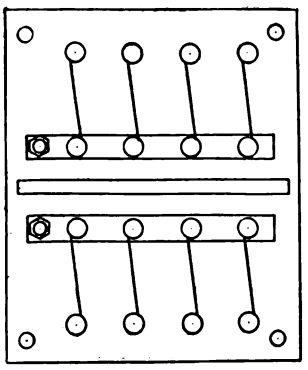
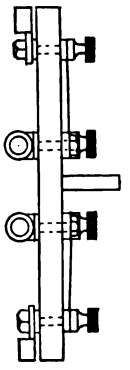


FIG. 4.



5. Sketch a distributing fuse-board for a voltage of 200, having bus-bars and four 25-ampere ways. State the important points in construction, the materials you would employ, and give all the essential dimensions.

The essential points in a distributing fuse-board are: (1) Proper separation of the poles in order to prevent accidental short-circuit. (2) High insulation. (3) Length and nature

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of fuse-wire, which must be chosen so as to preclude any possibility of the arc being sustained on blowing, and also to avoid unsatisfactory action owing to the cooling effect of the terminals. (4) Ease of access for connecting up and the replacement of fuses. (5) Ample carrying capacity of all parts.

Point (1) is efficiently met by placing a piece of slate between the poles as shown (Fig. 4), measuring approximately 2 inches deep by $\frac{1}{2}$ inch thick. (2) By the use, as a base, of good enamelled slate, free from metallic veins, and kept clear from the wall by the outside casing or wooden distance pieces. (3) By arranging for a break of $2\frac{1}{2}$ in., and the use of copper fuse wire, in this case of about No. 20 gauge. (4) By adopting a design that gives plenty of room everywhere, especially between the respective circuits; and a casing as shallow as circumstances permit. Clip fuses are the handiest for replacement, and are to be recommended. (5) By the use of copper or brass 'bus-bars and fittings of ample section, and connection by means of lugs sweated on to the cable ends.

In the above sketch (Fig. 4) the chief dimensions, which are ample, are:—Base, 10 inches × 12 inches × $\frac{3}{4}$ inch. Length of break, $2\frac{1}{2}$ inches. Centres of circuit terminals 2 inches. 'Bus bars $8\frac{1}{2}$ inches × $\frac{3}{4}$ inch × $\frac{1}{4}$ inch.

6. To determine the insulation resistance of a pair of live mains, the following tests were made, using a voltmeter of 10,000 ohms resistance:—

P.D. measured between the mains = 216 volts
,, ,, (+)main and earth = 196 ,,
,, ,, (−) ,, ,, = −10 ,,

Find the insulation resistance of each main from earth, and also the insulation of the whole system.

The voltmeter readings give the true voltage across the terminals of the instrument; but on connecting the voltmeter between a main and the earth, the current distribution is altered, so that the reading does not indicate the voltage between the main and the earth *before the instrument was connected up*. This explains the fact that, while the voltage across the mains is 216 volts, the (+) main is *apparently* 196 volts above the earth, while the (−) main is *apparently* 10 volts below the earth, thus giving an apparent P.D. between the mains of 196 + 10 = 206 volts.

When the voltmeter is connected between the (+) main and the earth, let c_1 be the current flowing to earth through the voltmeter, while c_2 is the current flowing to earth through the insulation. Let R_1 be the insulation resistance between the (+) main and earth. In passing from the (+) main to the earth, the same drop of potential will occur, whether we proceed by way of the voltmeter, or through the insulation. Thus since the voltmeter indicates 196 volts,

$$c_2 R_1 = 196 \quad \therefore c_2 = \frac{196}{R_1}.$$

When a P.D. of 1 volt is maintained across the voltmeter terminals, one division deflection will be produced; in this case the current flowing through the voltmeter will be equal to

$$\frac{1}{10{,}000} = 0{\cdot}0001 \text{ ampere.}$$

Hence, with a reading of 196 divisions, the current c_1 flowing through the voltmeter will be 0·0196 amperes.

$$\therefore c_1 + c_2 = 0{\cdot}0196 + \frac{196}{R_1}.$$

Let R_2 be the insulation resistance of the (−). main. The current entering the (−) main will now be equal to $(c_1 + c_2)$, and the P.D. between earth and the (−) main will be $(c_1 + c_2) R_2$. Since the constant P.D. between the mains is equal to 216 volts, we have, adding the P.D. between (+) main and earth, to P.D. between earth and (−) main:—

$$216 = 196 + \left(0{\cdot}0196 + \frac{196}{R_1}\right) R_2 \quad . \quad . \quad (1)$$

$$\therefore \frac{20}{R_2} = 0{\cdot}0196 + \frac{196}{R_1} \quad . \quad . \quad (2)$$

When the voltmeter is connected between (−) main and earth, the instrument indicates − 10 volts; *i.e.*, that the negative main is *now* 10 volts lower than the earth. Let c_3 be the current now flowing through the voltmeter, while c_4 is the current flowing from earth through the insulation of the (−) main. Then

$$10 = c_4 R_2 \quad \therefore c_4 = \frac{10}{R_2}$$

For reasons similar to those explained in finding c_1, the value of c_3 will be 0·0010 amperes.

$$\therefore c_3 + c_4 = 0{\cdot}0010 + \frac{10}{R_2}.$$

Then, since the current leaving the (+) main is now equal to $c_3 + c_4$, we have

$$216 = 10 + \left(0{\cdot}0010 + \frac{10}{R_2}\right) R_1 \quad . \quad . \quad (3)$$

Obtaining the value of $\frac{10}{R_2}$ from (2), and substituting in (3), we have

$$206 = \left(0{\cdot}0010 + 0{\cdot}0098 + \frac{98}{R_1}\right) R_1$$
$$= 0{\cdot}0108\, R_1 + 98;$$
$$\therefore R_1 = \frac{108}{0{\cdot}0108} = 10{,}000 \text{ ohms.}$$

Substituting in (2), we obtain

$$\frac{20}{R_2} = 0{\cdot}0196 + 0{\cdot}0196$$
$$= 0{\cdot}0392;$$
$$\therefore R_2 = \frac{20}{0{\cdot}0392} = 512 \text{ ohms.}$$

Therefore the insulation resistance between the mains is equal to

$$R_1 + R_2 = 10{,}000 + 512 = 10{,}512 \text{ ohms.}$$

(To be concluded.)

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REVIEWS.

Notes on the Composition of Scientific Papers. By T. Clifford Allbutt, M.A., M.D., etc., Regius Professor of Physics in the University of Cambridge. pp. viii. + 151. (London: Macmillan & Co., 1904.) Price 3*s.* net.

This useful volume may confidently be recommended, not only to students, but to all who may be called upon to express themselves in writing. Sound English, logical connectedness, and lucid expression of thought are necessary to the scientific journalist and the professor, no less than to the student about to test his acquirements in an examination. Many scientific papers, though containing information of the most valuable character, fail to obtain the attention they merit, owing to defects in their composition. Mr. Allbutt's experience has been wide, and his advice is valuable. He does not merely deal with principles, but shows, by well-chosen examples, how the commonest errors arise, and how they may be avoided. He does not present us with a dissertation on style and composition, but aptly instances the evils of ambiguity and loose diction. Some of the looseness often met with in modern writing is traced to the fact that authors frequently dictate to a short-hand clerk. There are few people whose spoken utterances can bear the close scrutiny to which printed matter is subjected. The scientist describing an invention or discovery should be as careful in his descriptions and arguments as a lawyer in drawing up a deed. It is beyond the range of any book to endow its readers with lucidity and exactness of expression; but no one who reads Mr. Allbutt's work with due care can fail to profit thereby.

A Text-Book of Geology: intended as an introduction to the study of the rocks and their contents. By W. Jerome Harrison, F.G.S., Chief Science Demonstrator for the Birmingham City Committee of Education. pp. viii. + 350. (London: Blackie & Son, 1903.) Price 3*s.* 6*d.* net.

This book has already run through four editions, and the issue of a fifth edition is a sufficient proof of its usefulness. The whole of the matter has been brought up to date, thus providing the student with the latest and most trustworthy information. Full advantage has been taken of modern methods of reproduction; although diagrams are useful, and even, in many cases, indispensable, yet a good photograph of a rocky shore, or a frowning cliff, conveys an idea of reality which could not otherwise be obtained.

In geology, as in all other sciences, constant and rapid progress is being made. Our knowledge of the rocks has recently been much enriched, so far as concerns the strata forming the beginning and end of the geological series. Consequently, up-to-date information on these strata is particularly acceptable to the student. It has been remarked, that "geology cannot be learnt from books;" but it is equally true that geology cannot be learnt *without* books. The rocks themselves are doubtless the best teachers; but if we remember the ages through which their tuition has been extended to mankind, and the comparatively slow progress made by each generation, then we are not likely to undervalue a volume which provides us with a succinct epitome of the knowledge laboriously amassed by mankind up to the present date.

Dynamo Attendants and their Dynamos; with a Section on Motors and Motor Driving. A practical book for practical men. By Frank Broadbent, M.I.E.E. pp. xvi. + 110. (London: Sidney Rentell & Co., Limited, 1904). Price 1*s.* 6*d.* net.

This work was originally written by Mr. Alfred Gibbings, M.I.E.E., but the fourth edition has been entirely re-written, with Mr. Gibbings' permission, by Mr. Frank Broadbent. It contains a simple exposition of the dynamo from a practical standpoint. Commencing with a general description of alternating and continuous-current dynamos, attention is next devoted to the choice of a dynamo or motor, methods of erecting, driving, starting, stopping, and paralleling dynamos; faults and breakdowns, and the construction, starting, stopping, and speed regulation of motors. Alternating and polyphase motors are also dealt with. The diagrams are good, but the lettering is very small and somewhat trying to those who cannot boast of keen sight.

Notes on Alternate Currents, for Students. By Harold H. Simmons, A.M.I.E.E. pp. 94. (London: Cassell & Co., 1904). Price 1*s.* 6*d.* net.

The study of alternate currents presents considerable difficulties to the average student, and is often given up as hopeless on account of the inadequate treatment sometimes met with in works on electrical engineering. Mr. Simmons is a well-known teacher, and requests from his students, past and present, have induced him to issue these notes, which form part of a larger work on electrical engineering which the author has in preparation. Students commencing the study of alternate currents cannot do better than to carefully study these notes.

America at Work. By John Foster Fraser. pp. viii. + 264. (London: Cassell & Co., Limited, 1904). Price 3*s.* 6*d.*

After reading this interesting and attractively got-up volume, no one will wonder that a new edition has been issued in practically each month since March, 1903, when the first edition appeared. The American citizen is presented to us in various aspects, mostly relating to his business career. We find him energetic, resourceful, undaunted by difficulties, somewhat disdainful of prejudices in which he does not share; but always with a keen eye to business. The chapter on the "Newest New York" may well make us wonder at the triumphs which engineering can effect, when applied to the construction of buildings; few of us, however, would wish to see London "new," if newness is inseparable from twenty-storey buildings. In the twenty-two chapters comprised in Mr. Fraser's

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book, such diverse subjects as the building of railway engines, commercial training, farming and agricultural colleges, railways and railway travelling, hog-killing and packing in Chicago, Niagara in harness, manufacture of boots and shoes, coal-mining, the cotton industry, and many others, are touched upon. Mr. Fraser owns to having seen, in the United States, much that is wonderful, much that we might profitably imitate, and perhaps a good deal that we ought to avoid. Finally, he says :—

"We have taught the United States many things. Indeed, the best of all they have, has been learnt from us. But whilst we have been resting on our oars, they have been swirling ahead.

"I gathered many things in the course of my investigations. One of the principal facts was that, man for man, the British workman is the superior of the American. The weak link was the capability of the employers, the administration of great concerns. In adaptiveness, in resource, in ingenuity, in whole-souled keenness to succeed, the average American manufacturer is by far the superior of his British compeer.

"If he would but rouse himself, the British manufacturer could soon alter this state of affairs ; and it is for this reason I respectfully invite him to learn something from 'America at Work.'"

THE FLAT-IRON, NEW YORK.
(From "America at Work," by John Foster Fraser.)

Oil Engines : their Selection, Erection, and Correction. By W. A. Tookey. pp. 138. (London : Merritt and Hatcher, Ltd , 1904.) Price 1*s.* net.

There are so many circumstances in which oil engines may profitably be used, that a simple account of their nature and method of use is likely to prove generally useful. The work at present under consideration has not been written from a scientific standpoint; for instance, no mention is made of indicator diagrams, and what can be learnt from them. Nevertheless, much useful information of a practical kind is presented in a readable form, and many of those whose interest in oil engines centres in keeping them in working order, rather than in perfecting their design, may find it of greater use than a more pretentious volume. It is a mistake, however, to issue a book of this kind without an index.

X-Rays Simply Explained. A Handbook on the Theory and Practice of Radiography. By R. P. Howgrave-Graham, A.I.E.E. pp. 92. (London : Percival Marshall and Co., 1904). Price 6d. net.

This book contains an account of the elementary principles involved in Röntgen ray work, together with the description of the methods of using the necessary apparatus. It is clearly written, and will prove useful to the large number of people who are anxious to obtain experimental familiarity with this fascinating branch of science.

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ANSWERS TO QUERIES.

Students wishing for the solution of problems, or assistance in their scientific or technical studies, are invited to consult the Editor by letter. Queries should be accompanied by the name and address of the sender, together with a nom de plume *for publication. Queries obtained from text-books or examination papers should be accompanied by particulars of the sources from which they are derived. Queries should reach us before the 10th of the month, to be answered in the next month's issue. Each inquirer is restricted to one query per month.*

HAMMER.—A 24 lb. hammer-head is suspended by a piece of fine steel wire 6 feet long, and is compelled to move in the arc of a circle after the manner of a plumb-bob. It is momentarily kept at rest at a point in the arc 4 feet vertically above the lowest point of the arc. At the lowest point of the arc there is placed a metal bar ⅜ inch square, resting transversely on supports 6 inches apart horizontally. The hammer-head being released, fractures the bar by striking it in the middle of the 6-inch length referred to, and continues its course until a height of 2 feet vertically above the lowest point of the arc is reached. The bar offered resistance to fracture through a distance of 2 inches in the hammer-head's path. Find the breaking strength of the material per square inch of section.

The 24 lb. hammer-head, in descending 4 feet, acquires kinetic energy amounting to

$$4 \times 12 \times 24 = 1{,}152 \text{ inch-lbs.}$$

After breaking the bar, the hammer-head ascends to a height (2 feet) equal to half that through which it previously fell. Hence half the energy acquired by the fall is lost in breaking the bar. Let F be the average force, in lbs., which the bar opposes to the hammer-head. Then, since the bar opposes the motion of the hammer-head through a distance of 2 inches,

$$2 \times F = \frac{1{,}152}{2}$$

$$\therefore F = 288 \text{ lbs.}$$

It would appear, from the question, that the bar merely *rests* on the supports, without being clamped or fixed in any way. In this case the distance between the supports does not come into the calculation; but the length of the bar (which is not mentioned) must be known. The impact of the hammer-head will set the bar in motion in a horizontal direction. Let l be the length of the bar. If f represents the force with which the bar opposes the motion of the hammer-head at any particular instant, then this force is utilised in accelerating the bar's motion. Midway between the centre point and either end of the bar, apply two opposite forces, each numerically equal to $f/2$. Then the force applied in the direction of motion will produce the required acceleration of the half of the bar under consideration; while the opposite force, combined with half of the force which the hammer-head exerts on the point of impact, will produce a turning moment equal to

$$\frac{f}{2} \times \frac{l}{4} = \frac{fl}{8} \quad . \quad . \quad . \quad . \quad (1)$$

Now we may assume that the force exerted on the bar by the hammer-head increases regularly from zero (at the instant when the bar is just touched) to a maximum value (when the bar breaks); thus since F is the *average* force exerted over the distance of 2 inches, the maximum force will be equal to 2 F, or 576 lbs. Substituting this value for f in (1), we find that the bending moment, at the instant when the bar is about to break, is equal to

$$\frac{576\,l}{8} = 72\,l \quad . \quad . \quad . \quad . \quad (2)$$

Owing to the bending of the bar, the fibres on the front (convex) side will be in tension, while those on the opposite side will be in compression. The corresponding forces called into play will produce a turning moment equal and opposite to that given by (2). It can be proved (*see* TECHNICS, current issue, p. 604) that if F denotes the maximum stress (*i.e.*, the stress called into play by the elongation or compression of the surface fibres), then the turning moment will be equal to

$$\tfrac{1}{6}\,b\,d^2\,F$$

where b represents the breadth, and d the depth, of the beam. In the present instance, $b = d = \frac{3}{8}$ inch. Then

$$72\,l = \tfrac{1}{6}\,(\tfrac{3}{8})^3\,F$$

$$\therefore F = 8{,}192\,l.$$

This value of F gives the required breaking stress of the bar, in lbs. per square inch.

MODULUS.—A watch has a non-compensated brass balance wheel and a steel balance spring. How many seconds will it lose per day for a 1° C. rise of temperature, if the coefficient of linear expansion of brass is 18×10^{-6}, while Young's modulus of steel at t° is

$$2 \times 10^{12}\left(1 - \frac{2t}{10^4}\right)?$$

—London University, B.Sc. (Pass), 1902.

Let M be the mass of the balance wheel, and k its radius of gyration. Then the moment of inertia of the wheel is equal to Mk^2. Let l be the length of the spring, and Y Young's modulus for the substance of which the spring is composed. Then it can be proved that T, the time of one complete oscillation, is given by the equation

$$T = 2\pi\sqrt{\frac{Mk^2 l}{Y}}.$$

Now the number of oscillations performed in

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a second will be equal to 1/T, and the number performed in 24 hours will be equal to

$$\frac{86{,}400}{T} = \frac{86{,}400}{2\pi k}\sqrt{\frac{Y}{Ml}}.$$

Therefore, if n = number of oscillations performed per day,

$$n \propto \frac{Y^{\frac{1}{2}}}{k}\ ; \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

since M, the mass of the balance wheel, is essentially constant, and the expansion of steel is so small that l may be considered to be invariable.

At first let the temperature be $t°$, and let Y be the value of Young's modulus for the steel at that temperature. If the temperature rises through 1°, Young's modulus will become

$$\frac{\left(1-\frac{2(t+1)}{10^4}\right)}{1-\frac{2t}{10^4}}\,Y = \left(1-\frac{\frac{2}{10^4}}{1-\frac{2t}{10^4}}\right)Y$$

The quantity within the brackets on the right-hand side of this equation will differ but little from unity; and we may therefore neglect the quantity $(2t)/10^4$ in the denominator, since this small quantity is to be subtracted from 1, and neglecting it will make only a small percentage difference in a term which is already small. Hence Young's modulus, after a rise of 1° C, will be equal to

$$(1-2\times10^{-4})\,Y.$$

With a rise of 1° C, k will be changed into $k\,(1+1{\cdot}8\times10^{-5})$. Hence, if n_1 = no. of oscillations per day when temperature = $t°$, n_2 = number of oscillations per day when temperature = $(t+1)°$

$$\frac{n_2}{n_1} = \frac{(1-2\times10^{-4})^{\frac{1}{2}}}{1+1{\cdot}8\times10^{-5}}$$

Expanding by the aid of the binomial theorem, we obtain

$$\frac{n_2}{n_1} = (1-1\times10^{-4}+\ldots.)(1-1{\cdot}8\times10^{-5}+\ldots.)$$
$$= (1-0{\cdot}0001-0{\cdot}000018+\ldots.)$$
$$= 1-0{\cdot}000118,$$

neglecting squares and higher powers of small quantities.

$$\therefore\ 1-\frac{n_2}{n_1} = \frac{n_1-n_2}{n_1} = 0{\cdot}000118.$$

Now $n_1 - n_2$ is the number of oscillations lost per day: $(n_1-n_2)/n_1$ may be taken, either as the ratio of the number of *oscillations* lost per day to the number normally performed per day; or the number of *seconds* lost by the watch per day, to the number of seconds per day. Therefore the number of seconds lost per day

$$= 86{,}400 \times 0{\cdot}000118 = 10{\cdot}2 \text{ secs.}$$

ALPHA.—An upright pole 10 feet high casts a shadow 12·6 feet long at mid-day on a certain day. Another upright pole of the same height, 100 miles further north, casts a shadow 13·2 feet long at the same time. Deduce the earth's perimeter, supposing the earth to be a sphere.—*Entrance Exam., Woolwich, Math. II.*, 1903.

Let A B (Fig. 1) represent the first rod, while S_2 B C is a ray from the sun which just passes the top of the rod. Then A C will represent the shadow thrown by the first rod. Let D E represent the second rod, throwing a shadow D F. Owing to the great distance of the sun, the rays S_2 B C and S_1 E F will be practically parallel.

Let M be the centre of the earth. Since the rods A B and D E are upright (*i.e.*, normal to the surface of the earth) B A and E D produced will meet at M. Produce S_2 C to cut M D in K.

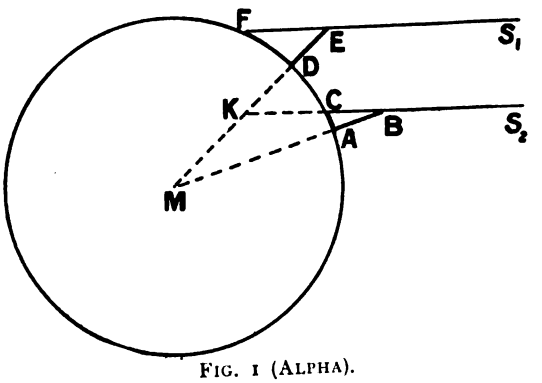

FIG. 1 (ALPHA).

Then, since E K B is an external angle of the triangle B K M, we have

$$\angle EKB = \angle KMB + \angle KBM$$
$$\therefore \angle KMB = \angle EKB - \angle KBM$$

Further $\angle FEK = \angle EKB$, since E K cuts the parallel lines S_2 K and S_1 F.

$$\therefore \angle KMB = \angle FEK - \angle KBM \quad . \quad . \quad (1)$$

Since the arcs D F and A C are small, we may treat the figures F D E and C A B as small right-angled triangles. Then, using a table of natural tangents, we have

$$\tan FEK = \frac{DF}{DE} = \frac{13{\cdot}2}{10} = 1{\cdot}32$$
$$\therefore \angle FEK = 53° \text{ (nearly)}$$
$$\tan KBM = \frac{AC}{AB} = \frac{12{\cdot}6}{10} = 1{\cdot}26$$
$$\therefore \angle FEK = 51°{\cdot}5 \text{ (nearly).}$$
$$\therefore \text{from (1)}, \angle KMB = 53-51{\cdot}5 = 1°{\cdot}5$$

Thus the arc A D, 100 miles in length, subtends an angle of 1°·5 at the centre of the earth. Consequently the complete periphery of the earth, subtending an angle of 360° at the centre, will measure

$$\frac{360}{1{\cdot}5}\times 100 = 24{,}000 \text{ miles.}$$

ACCELERATION.—Two cubes of iron, weighing 4 ozs. and 4 lbs. respectively, are dropped from a height of 500 ft.: which will reach the ground first (1) in the open air, and (2) in a vacuum?

When the cubes are dropped *in vacuo*, they will both reach the ground in equal times.

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Since the pull of gravity is proportional to the mass acted upon, it follows that each gram (say) of the mass will be acted upon by the same force that would act upon the gram if it were isolated, and thus we may consider gravity to accelerate the motion of each gram independently.

When the two are dropped in the open air, the larger cube will reach the ground first. This is due to two causes :—

(1) The motion of a body through the air compresses the air in front of it, and produces a partial vacuum behind it. This tends to stop the motion of the body. The cross-section of the cubes will vary as the square of their linear dimensions, while the mass (which depends on the cubic content) varies as the cube of the linear dimensions. The ratio of the pull of gravity to the resistance of the air will vary as the linear dimensions of the body ; thus the larger the body the smaller will be the effect of air resistance—provided, of course, that the bodies are equal in density.

(2) Another source of resistance to the motion of a body in air, is what is termed *skin friction*. When a surface is moved through the air, the direction of motion being tangential to the surface, there is a certain amount of friction between the surface and the adjacent air. The effect of this friction, on bodies of different sizes, resembles that already described.

When a body moves through a fluid with small velocity, the resistance is chiefly due to skin friction, and varies directly as the velocity. When the velocity is high, the resistance is chiefly due to the displacement of the fluid, and varies as the square of the velocity. For intermediate velocities the resistance varies as the velocity raised to the power 3/2.

A BEGINNER.—A microscope is made up of an objective of ⅛ inch focal length and an eye-piece of 1 inch focal length, placed 6 inches apart. A person uses it to look at a small arrow-shaped object, his distance of distinct vision being 8 inches. Where must the object be placed ?— *London University, Inter. Sci. Hons.*, 1894.

The observer's eye is placed as near as possible to the eye-piece lens, and the virtual image seen must be 8 inches away from the eye, and therefore practically the same distance from the lens. Let u be the distance from the eye-piece lens to the real image formed by the objective ; then since focal length of the eye-piece lens $= -1$ inch, we have

$$\frac{1}{8} - \frac{1}{u} = -\frac{1}{1} \quad \therefore \quad \frac{1}{u} = 1 + \frac{1}{8} = \frac{9}{8}$$

$$\therefore \quad u = \tfrac{8}{9} \text{ inch.}$$

Thus the real image formed by the objective must be $6 - \frac{8}{9} = 5\frac{1}{9}$ ins. from the objective. Then, if we now denote the distance of the arrow-shaped object from the objective by u, we have, remembering that the focal length of objective $= -\frac{1}{8}$ in., and distance of image from objective $= -5\frac{1}{9} = -\frac{46}{9}$ in.

$$-\frac{9}{46} - \frac{1}{u} = -2 \quad \therefore \quad \frac{1}{u} = 2 - \frac{9}{46} = \frac{81}{46}$$

$$\therefore \quad u = \tfrac{46}{81} = 0{\cdot}567 \text{ in.}$$

CATFORD.—What are the difficulties encountered in constructing a small internal combustion motor, to utilise the motive power furnished by the explosion of a mixture of hydrogen and oxygen, in the proportion of two volumes of hydrogen to one volume of oxygen ?

The combustion of hydrogen and oxygen could be utilised to drive a motor, but the following reasoning shows that the cylinders would have to be much larger than if petrol vapour were used, and the cost of working would be much higher.

A *gram* of hydrogen, when exploded with the requisite quantity of oxygen, generates more heat than the combustion of a gram of any other substance. But hydrogen is less dense than any other substance, so that a gram of hydrogen would occupy far more space than a gram of any other substance. A cubic foot of hydrogen, under normal atmospheric pressure, would produce, if burnt with a sufficient supply of oxygen, 68,700 gram-calories which could be utilised in an internal combustion engine : the combustion of a cubic foot of methane (CH_4) under similar conditions would produce 232,000 available gram-calories : the combustion of a cubic foot of ethylene would produce 381,000 available gram-calories ; while the combustion of a cubic foot of benzene vapour would produce 902,000 available gram-calories. Since the object of an internal combustion engine is to produce heat by chemical combination, and then convert as much as possible of this heat into mechanical energy, it is easily seen that the volume of the cylinder of a hydrogen engine would have to be much greater than that of an engine utilising the other combustible vapours mentioned, or else the hydrogen would have to be delivered to the cylinder at a pressure much higher than atmospheric. Further, hydrogen is a comparatively expensive substance ; so that, finally, a combustion engine designed to utilise hydrogen would be more expensive to construct than an ordinary engine, and the working costs would also be much higher.

CATALYTIC IGNITION.—What is meant by the term "catalytic ignition" as applied to explosion motors ?

Certain substances, such as platinum and palladium, become intensely heated when exposed to a stream of oxygen and hydrogen, the temperature attained being sufficient to explode the mixture. Automatic gas lighters have been made, using a piece of palladium foil or wire, which is placed above the burner in the stream of issuing gas : the wire becomes red-hot and ignites the gas. Similar principles have been used, without very great success, to ignite the explosion mixture in internal combustion engines. The chief disadvantages are, that the ignition cannot be regulated so as to occur just when required ; also, a layer of grease on the catalytic substance (palladium or platinum) stops the action.

ALPHA.—Is it possible to disinfect the air, say of a sick room, by means of electricity ? If so,

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what is the reaction, and which would be the cheapest and most effectual way of doing it? I may mention that I have a small induction coil, also a small ozoniser.

*The point raised is one of importance and deserves attention. As yet the question has not been seriously studied, but from what we know of the methods of producing ozone it would appear that it is hardly practicable to disinfect the air of a room by means of this gas. The usual ozonisers are Siemen's, Berthelot's and Brodie's—the last being best—see Travers on Gases, p. 54, and A. Eberhard's *Utensilien*, for diagrams. These instruments are intended for use with pure oxygen, since the presence of nitrogen gives rise to the formation of oxides of that element, and some of the higher oxides would react with the ozone and remove the third atom from the molecule and thus render the latter inert as a disinfectant. At any rate, but feeble results are obtained from passing a stream of air through the ozoniser under the most favourable conditions, *viz.*, using Brodie's design of instrument at a moderate potential difference and at a low temperature. Last year the writer made the following experiment with the view of ascertaining whether fruit might be preserved from deterioration by treatment with ozonised air in a vessel afterwards hermetically sealed. The fruit was placed in a glass cylinder with metallic ends; and air, which had passed through an ozoniser, was admitted at one end by a metal tube bent into a knee and loosely packed with fusible metal. At the other end was an exactly similar metal tube, leading first to a meter and thence to an aspirator. When a volume of ozonised air equal to ten times the volume of the cylinder had been passed through, the cylinder was sealed up by melting the fusible metal with a spirit lamp. The experiment showed that carefully selected and sound fruit was not protected in several instances, notably in the case of peaches and strawberries. From experiments made in Manchester with Croft's patent fusible metal valve, it appears that fruit which has been similarly treated with air that has bubbled through 4% formalin remains intact for a long period.

There is a point which does not seem to have occurred to "Alpha," and it is this: Would it be advisable to use ozone for disinfecting, even if it were practicable to pass a certain portion of the air entering the room through an ozoniser? The writer inclines to doubt the wisdom of such an enterprise. For ozone is an irritating gas when it comes into contact with mucous membranes, and air surcharged with it "feels" very much like a chlorinated atmosphere. Like chlorine, it has excellent disinfecting properties when so much as one per cent. is present; but not even with Brodie's ozoniser can one obtain half of one per cent. of ozone when ordinary air is being transmitted. Nothing short of ozonising the whole air in the sick room would be likely to prove efficaceous, and the result would probably be more disagreeable to the patient, than destructive to micro-organisms and their spores.

*Answer to "Open Query" in February TECHNICS, for which a prize of £3 was awarded to John Don, 53, King Street, Peterhead

GREEN.—The pitch of a screw propeller is 18 ft.: slip 10 per cent.: speed of ship, 15 knots. Find the revolutions per minute. What is the thrust, if the actual horse-power spent by the propeller is 2,000, and the waste by surface friction is 30 per cent.? What is the torque in the shaft?—*Prof. Perry's "Mechanics," p. 105, No. 4.*

If we had a screw with a pitch of 18 ft., working in a stationary nut, then this screw would travel 18 ft. parallel to the axis for every complete revolution. To a certain extent the screw propeller acts like a screw, the water taking the place of a nut; but since the slip is here 10 per cent., it will travel only $18(1-0{\cdot}1)=16{\cdot}2$ ft. forward for each complete revolution.

1 knot = 6,080 ft. per hour.

Then, if n = no. of revolutions per minute,

$$60\,n \times 16{\cdot}2 = 6080 \times 15;$$

$$\therefore\ n = \frac{6080 \times 15}{60 \times 16{\cdot}2} = 93{\cdot}8 \text{ R.P.M.}$$

The *thrust* is the force with which the propeller pushes the water backwards, or the ship forwards. Let f be the thrust, in lbs. Then, since 30 per cent. of the power is wasted in overcoming surface friction, the power utilised in propelling the ship is $2{,}000\ (1-0{\cdot}3) = 1{,}400$ h.p. Since the speed of the ship is $(6080 \times 15)/60 = 1{,}520$ ft. per minute, and 1 h.p. = 33,000 ft. lbs. per minute,

$$f \times 1{,}520 = 1{,}400 \times 33{,}000;$$

$$\therefore\ f = \frac{1{,}400 \times 33{,}000}{1{,}520} = 30{,}400 \text{ lbs. (nearly).}$$

It is easily proved that if T is the torque in the shaft, while n is the number of revolutions per minute, then $2\pi n\,\mathrm{T}$ = total power, in ft.-lbs. per minute developed. Then, since $n = 93{\cdot}8$,

$$\mathrm{T} = \frac{2{,}000 \times 33{,}000}{2\pi \times 93{\cdot}8} = 112{,}000 \text{ lb. ft.}$$

STUDENT Y.—Explain why the integral of du is independent of the path, and depends only on the initial and final states, provided du is a complete differential; while the value of the integral depends on the path when the differential is incomplete.

In answering this question, let us suppose that u is a function only of the variables x and y. When the explanation depending on these conditions has been grasped, the reasoning may readily be extended to the case of a function of any number of variables.

Thus $u = f(x, y)$.

If du is the complete differential of u, then

$$du = \frac{\delta f}{\delta x}\,dx + \frac{\delta f}{\delta x}\,dy,$$

where $\frac{\delta f}{\delta x}$ denotes the differential coefficient of $f(x, y)$ with regard to x, treating y as a constant; and $\frac{\delta f}{\delta y}$ denotes the differential co-

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efficient of $f(x, y)$ with regard to y, treating x as a constant. It can easily be proved that

$$\frac{\delta}{\delta y}\frac{\delta f}{\delta x} = \frac{\delta}{\delta x}\frac{\delta f}{\delta y}.$$

Thus if

$$du = X\,dx + Y\,dy, \quad . \quad . \quad . \quad . \quad (1)$$

the condition that du shall be a complete differential, is that

$$\frac{\delta X}{\delta y} = \frac{\delta Y}{\delta x}.$$

Now let V be a vector quantity, its value varying from point to point of the x, y plane (Fig. 1); also let X, Y, be the components of V, at any point (x, y), resolved parallel to the axes of x and y. Let it be required to resolve V parallel to each element of a path A B C, multiply by the length of the element of path, and integrate over the complete path A B C. Let dx and dy be the resolved components of

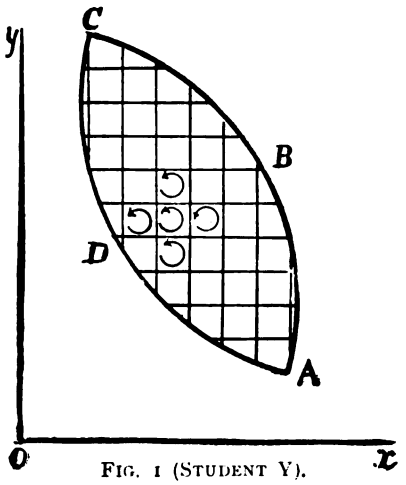

FIG. 1 (STUDENT Y).

an element of path, while X and Y are the corresponding values of the components of V; then the required differential du is given by

$$du = X\,dx + Y\,dy.$$

We must now find the condition that du, integrated along the path A B C, shall be equal to the integral along any other path A D C.

Divide the area A B C D A into small rectangular elements, by lines respectively parallel to the axes of x and y. Then if we find the line integral of V along the boundary of each of these elements, and add all of these line integrals together, we shall obtain the line integral of V along the closed path A B C D A. We must, of course, integrate round the boundaries of all elements in the same sense, *e.g.*, the anti-clockwise sense indicated by the curved arrows in Fig. 1; then it is easily seen that we shall proceed *twice* along each element of path, in opposite directions; with the exception of the elements of path which are equivalent to the path A B C D A, these latter elements of path being traversed once only. If the integral along the path A B C is to be equal to the integral along the path A D C, then the integral along the closed path A B C D A must be equal to zero; for since V is a vector quantity, the integral along the path C D A, will be equal to the integral along the path A D C with sign reversed. Thus, in order that the integral from A to C shall be independent of the path, the integral along any closed path from A to C and back to A must be zero. For this condition to be fulfilled, the sum of the integrals around all the small rectangular elements of area must be equal to zero; and for this to be true, whatever paths A B C and A D C are chosen, the line integral round each and every rectangular element of area must be equal to zero.

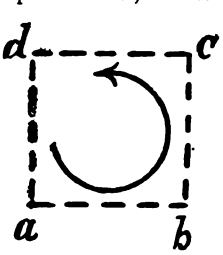

FIG. 2 (STUDENT Y).

Let a (Fig. 2) represent any point (x, y) in Fig. 1. Let the rectangle $a\,b\,c\,d$ represent one of the elements of area into which the space enclosed by the path A B C D A (Fig. 1) has been divided. Let X be the x components of V at the point a. Let $a\,b = dx$, while $a\,d = dy$. Then $X\,dx$ will give the line integral of V along $a\,b$.

If Y is the y component of V at a, then $\left(Y + \frac{\delta Y}{\delta x}\,dx\right)$ will be the y component of V at B; so that the line integral along $b\,c$ will be equal to $\left(Y + \frac{\delta Y}{\delta x}\,dx\right)dy$.

At d, the x component of V will be equal to $\left(X + \frac{\delta X}{\delta y}\,dy\right)$; thus, since $c\,d = -\,dx$, the line integral along $c\,d$ will be equal to $-$

$$-\left(X + \frac{\delta X}{\delta y}\,dy\right)dx.$$

Since $d\,a$ (Fig. 2) $= -\,dy$, and the y component of V at a is equal to Y, the line integral along $d\,a$ is equal to $-\,Y\,dy$.

Then the line integral around the boundary $a\,b\,c\,d\,a$ is equal to

$$X\,dx + \left(Y + \frac{\delta Y}{\delta x}\,dx\right)dy - \left(X + \frac{\delta X}{\delta y}\,dy\right)dx - Y\,dy = \left(\frac{\delta Y}{\delta x} - \frac{\delta X}{\delta Y}\right)dx\,dy.$$

For this quantity to be equal to zero,

$$\frac{\delta Y}{\delta x} - \frac{\delta X}{\delta Y} = 0$$

which is the condition that (1) shall be a complete differential.

J. C.—Try whether the equation to the given

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curve * P P (Fig. 1) can be expressed approximately in the form

$$y\,(x+a)^n = c;$$

and if so, find the best average values of a, n, and c, the coordinates, being measured in centimeters from the given axes. — *Board of Education, Geometry, Honours*, 1904.

The solution of this problem can most readily be obtained by finding dy/dx, the tangent of the angle of slope of the curve, at different points. For the graphical method of determining dy/dx at different points of a given curve, *see* answer to *Entrop*, TECHNICS No. 3 (March), page 303. It must be remembered, however, that if the curve slopes downwards from left to right, dy/dx will be negative: if it slopes upwards from left to right, dy/dx will be positive.

From Fig. 1, we have

When—

$x = 1, y = 3{\cdot}53, dy/dx = -\tan\theta_1 = -0{\cdot}88$
$x = 3, y = 2{\cdot}5, \quad dy/dx = -\tan\theta_2 = -0{\cdot}31$
$x = 5, y = 2{\cdot}04, dy/dx = -\tan\theta_3 = -0{\cdot}17.$

Now let x, y be the coordinates of any point of the given curve; then we may assume for the moment that

$$y\,(x+a)^n = c \quad . \quad . \quad . \quad . \quad (1)$$

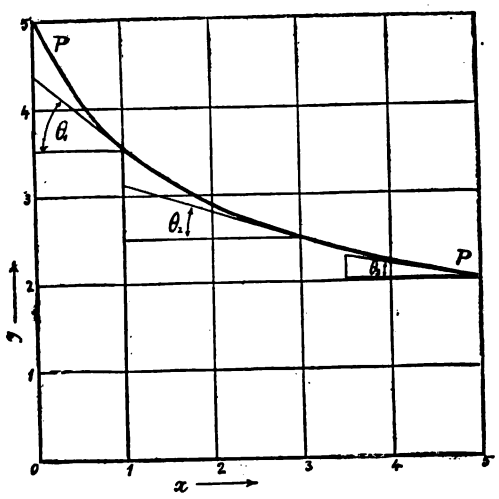

FIG. 1 (J.C.).

Let $x + dx$, $y + dy$, be the coordinates of a neighbouring point on the curve; then the symbol dy, taken as a whole, represents the increase in y corresponding to an increase dx in x; and dy/dx represents the tangent of the angle of slope of the curve at the point (x, y). Since the point $(x + dx, y + dy)$ lies on the given curve, we must have

$$(y+dy)\,(x+dx+a)^n = c = y\,(x+a)^n \quad . \quad (2)$$

Dividing both sides of (2) by $y\,(x+a)^n$, we have

$$\left(1+\frac{dy}{y}\right)\left(1+\frac{dx}{x+a}\right)^n = 1. \quad . \quad . \quad . \quad (3)$$

* Fig. 1 is not identical with the curve given in the examination; it will, however, illustrate the method of procedure.

Expanding the second factor on the left-hand side of (3) by the binomial theorem, we have

$$\left(1+\frac{dy}{y}\right)\left(1+n\frac{dx}{x+a}+\frac{n(n-1)}{1\cdot 2}\left(\frac{dx}{x+a}\right)^2+\ .\ .\right)=1$$

Since dx is supposed to be very small, we may neglect terms involving powers of dx greater than unity, when we obtain

$$\left(1+\frac{dy}{y}\right)\left(1+n\frac{dx}{x+a}\right) = 1$$

multiplying out, and neglecting the term involving the *product* of the small quantities dy and dx, which will be very small in comparison with the remaining terms, we have

$$1+\frac{dy}{y}+n\frac{dx}{x+a} = 1;$$

$$\therefore \frac{dy}{dx} = -n\frac{y}{x+a} \quad . \quad . \quad . \quad . \quad (4)$$

Substituting in (4) values of dy/dx and y corresponding to $x = 1$, as determined from Fig. 1, we obtain

$$-0{\cdot}88 = -n\frac{3{\cdot}53}{1+a}$$

$$\therefore 0{\cdot}88 + 0{\cdot}88a = 3{\cdot}53n \quad . \quad . \quad . \quad (5)$$

Substituting values of dy/dx and y corresponding to $x = 5$, we obtain, after simplifying,

$$0{\cdot}85 + 0{\cdot}17a = 2{\cdot}04n \quad . \quad . \quad . \quad (6)$$

(5) and (6) are two simultaneous equations in a and n; solving these by the usual method, we obtain

$$a = 1$$
$$n = 0{\cdot}5$$

On substituting these values of a and n in (4), together with $x = 3$, $y = 2{\cdot}04$, we find that

$$\frac{dy}{dx} = -0{\cdot}31,$$

which agrees with the value previously found directly from the curve. This proves that the true form of the equation is that given by (1).

To find the best *average* values of a and n, values of dy/dx should be found experimentally for (say) six points on the curve, so that six equations similar to (5) and (6) are obtained. Add three of these equations together to form a single equation in a and n, and then add the remaining three together to form another equation in a and n; solve the two resulting equations as before.

The value of c is easily found by substituting in (1). Thus for $x = 1$, $y = 3{\cdot}53$, we have

$$3{\cdot}53 \times 2^{\frac{1}{2}} = c$$
$$\therefore c = 5$$

STRUT.—A rod of steel, 4 inches in diameter, 10 feet long, acts as a strut; but the resultant load does not act exactly at the centre of each end. The inexactness of loading is (say) h: imagine it to be the same at both ends. If the greatest stress in the material is not to exceed 20,000 lbs. per square inch, and if Young's modulus is 3×10^7 lbs. per square inch, find the greatest loads for the strut in three cases: (1) when $h = 0{\cdot}1$ inch; (2) when $h = 0{\cdot}01$ inch; and (3) when $h = 0$.—*Board of Education, Applied Mechanics, Honours*, 1904.

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Let W be the maximum permissible load. Let the points of application of the load at the ends of the strut be on opposite sides of the axis; then the turning moment of the load will be

$$W \times 2h = 2Wh \text{ lb. ins.}$$

The resisting moment due to the stretching of the fibres at the mid-section of the beam will be equal to

$$fI/y,$$

where f is the maximum stress per square inch, due to bending, I is the "moment of inertia" of the cross section of the strut, and y is the distance from the centroid of the section to the extreme surface fibres (see *Structural Design*, p. 605). In the case of a solid strut of circular section, the radius of the circle being r,

$$I = \frac{\pi r^4}{4}$$

Further, $y = r$;

Therefore, equating moments, we obtain

$$f \times \frac{\pi \times 2^4}{4 \times 2} = 2Wh$$

$$\therefore f = \frac{Wh}{\pi}$$

When the strut is loaded at the centre of each end, the uniform stress in the material is

$$\frac{W}{area} = \frac{W}{\pi \times 2^2}.$$

When the loading is inexact, maximum total stress

$$= \frac{W}{\pi \times 2^2} + \frac{Wh}{\pi} = \frac{W}{2\pi}\left(\tfrac{1}{2} + 2h\right);$$

$$\therefore W = \frac{2\pi \times 20{,}000}{\frac{1}{2} + 2h}.$$

When $h = 0$, W = 251,200 lbs.
When $h = 0{\cdot}01$ in., W = 241,500 lbs.
When $h = 0{\cdot}1$ in., W = 179,400 lbs.

PI.—Would you please explain a method of calculating π?

The most elementary, and at the same time the oldest, method is due to Archimedes. It consists in showing that the circumference of a circle must lie somewhere between the perimeters of circumscribed and inscribed polygons, and in calculating the perimeters in succession for 6, 12, 24, . . . sided regular polygons.

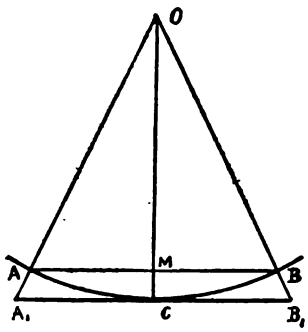

FIG. 1 (PI).

In the figure, A B is the side of a regular inscribed polygon, $A_1 B_1$ that of the circumscribed polygon.

Then

$$\frac{A_1 B_1}{A B} = \frac{O C}{O M} = \frac{O C}{\sqrt{O B^2 - \frac{A B^2}{4}}}$$

Hence, if r denote the radius O B,

$$i = A B,$$
$$c = A_1 B_1,$$

Then

$$c = \frac{r i}{\sqrt{r^2 - \frac{i^2}{4}}}$$

Again, the distance from A to C is the side of the regular inscribed polygon of double the number of sides; and if $A C = i_1$,

$$i_1^2 = \frac{i^2}{4} + \left(r - \sqrt{r^2 - \frac{i^2}{4}}\right)^2$$

$$= 2r\left(r - \sqrt{r^2 - \frac{i^2}{4}}\right)$$

and c_1, the side of the corresponding circumscribed polygon, is given by

$$c_1 = \frac{r i_1}{\sqrt{r^2 - \frac{i_1^2}{4}}}$$

If we take $r = \frac{1}{2}$, so that the diameter of the circle = 1, then

$$c = \frac{i}{\sqrt{1 - i^2}}, \quad i_1 = \tfrac{1}{2}\left(1 - \sqrt{1 - i^2}\right), \quad c_1 = \frac{i_1}{\sqrt{1 - i_1^2}}$$

By means of these formulæ, starting with a regular inscribed hexagon for which $i = r = \frac{1}{2}$, we can calculate in succession the length of sides for 12, 24, 48, 96, . . . sided polygons. The labour for the 96-sided polygons is, with care, very small, the perimeter of the circle of radius $\frac{1}{2}$ is thus found to lie between

3·140 and 3·142.

By using the formulæ

$$\text{Perimeter} \begin{cases} = 2nr \sin \frac{180}{n} \text{ (inscribed)} \\ = 2nr \tan \frac{180}{n} \text{ (circumscribed)} \end{cases}$$

and taking n the number of sides as 180, we at once obtain from tables that π lies between

3·1414 and 3·149.

By means of series obtained in Higher Trigonometry and the Calculus, the numerical work can be carried on more expeditiously. π has been calculated to 707 decimal places; correct to 21 figures it is

3·14159265358979323846.

INDUCTION MOTOR.—Describe the action of the induction motor. For moderate variations of the supply voltage V, and the current frequency n, and for small values of the slip δ, show that the torque of the motor is proportional to $\frac{V^2\delta}{n}$

The induction motor is a species of alternating-

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current transformer, and its theory is analogous to that of the transformer. In an identically similar manner electrical energy, in both cases, is transferred from the supply circuit to the secondary circuit by electro-magnetic induction. Briefly, the actions taking place are as follows :— Upon the stator winding receiving two or three-

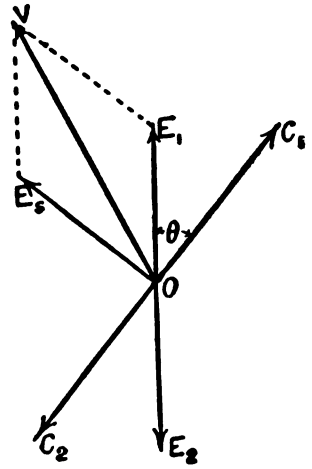

FIG. 1 (INDUCTION MOTOR).

phase currents, a rotary magnetic field is set up ; and as, at the first instant of closing the primary circuit, the rotor is at rest, and is situated within a rotary magnetic field, its coils are cut by the lines of force of the field revolving with an angular velocity Ω, and the rotor conductors become the seat of induced currents of the *same* frequency as that of the current supplied. These induced currents in the rotor set up a secondary magnetic field of their own, and in virtue of electro-magnetic reactions taking place, a definite turning moment is imparted to the rotor.

It is obvious that no induced E.M.F. would be produced if the rotor speed were stationary with respect to the primary rotating magnetic field ; in other words, if the speed of the rotor were equal to that of the primary field, the flow of magnetism through its coils would be stationary and constant in magnitude, and no E.M.F. could be induced therein. This is why the induced currents run after the field, and are not synchronous with it, and the production of the induced currents in the secondary (rotor) circuits gives rise to the resulting torque.

When the rotor is in motion the frequency n_2, of the induced currents is *not* the same as n_1, that of the stator currents, but is equal to $n_1 (1-\delta)$, where δ is the *slip*, this quantity being defined as the ratio of the difference between the impressed frequency of the primary magnetic field and the frequency of the rotation of the rotor, to the frequency of the primary magnetic field.

The determination of the magnitude of the torque may be effected as follows : Let L = the coefficient of self-induction of each stator circuit ; then the reactance is $j = 2\pi n L$; E_1 and E_2 = the stator and rotor E.M.F.'s respectively, which correspond to the useful magnetic flux under working conditions. These are represented graphically by $O E_1$ and $O E_2$ in Fig. 1. The currents C_1 and C_2, making an angle θ with E_1 and E_2 are represented by the vectors $O C_1$ and $O C_2$. Now the component of the E.M.F. of supply required to overcome the inductance is $E_s = j C_1$ and is normal to $O C_1$: it is represented by the vector $O E_s$. The E.M.F. of supply is V, and is obviously the resultant of $O E_1$ and $O E_s$; it is therefore given by the diagonal O V in the figure.

Now

$$C_2 = C_1 = \frac{E_2}{R} = \frac{\delta E_1}{R},$$

and if the power factor be unity and the current be in phase with the pressure, $\theta = 0$, and $O E_s$ would be normal to $O E_1$. Then, from the geometry of the figure

$$V^2 = E_1^2 + E_s^2 = E_1^2 + j^2 C_1^2$$
$$= E_1^2 + j^2 \frac{\delta^2 E_1^2}{R^2} \text{ (from above);}$$
$$\therefore E_1^2 = V^2 + \left(1 + \frac{j^2 \delta^2}{R^2}\right)$$
$$= \frac{V^2 R^2}{R^2 + j^2 \delta^2}$$

If P = power suppled to each primary circuit,

$$P = E_1 C_1 = \frac{\delta E_1^2}{R}$$
$$= \frac{\delta V^2 R}{R^2 + j^2 \delta^2};$$

and if P_1 = power wasted as heat,

$$P_1 = C_2^2 R = \frac{\delta^2 E_1^2}{R}$$
$$= \frac{\delta^2 V^2 R}{R^2 + j^2 \delta^2}$$

the power utilised is $P - P_1$ and

$$P - P_1 = \frac{(1-\delta)(\delta V^2 R)}{R^2 + j^2 \delta^2}$$

Let T = torque acting on the rotor per phase; then, since the work done is equal to the product of the torque and angular speed,

$$W = \frac{2\pi n_2}{p} T,$$

where p = number of phases.

Since $n_2 = (1-\delta) n_1$

$$\frac{(1-\delta)(\delta V^2 R)}{R^2 + j^2 \delta^2} = \frac{2\pi (1-\delta)}{p} n_1 T;$$
$$\therefore T = \frac{p}{2\pi n_1} \frac{\delta V^2 R}{R^2 + j^2 \delta^2}$$

or in words, the torque is proportional to

$$\frac{V^2 \delta}{n}$$

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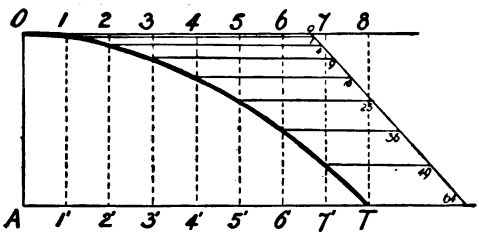
TECHNICS CORRESPONDENCE.

To the Editor of TECHNICS.

DEAR SIR,—In the following I beg to call your attention to a quick method of describing a parabola, applicable to the determination of the curve of bending moments, etc.

Let O A be the axis of a half parabola which is to pass through the vertex O and the point T. Divide each of the parallel sides of the completed rectangle, O A T 8, into eight equal parts. Then take a graduated rule or scale (a millimeter scale is best), and lay it obliquely on the drawing, in such a manner that the zero division is on the O 8 line and the division 64 (the square



of the number of the last division passing through T and 8) falls in the line A T. Then through the divisions 0, 1, 4, 9.....64 of the graduated scale draw parallels to A T, to meet the ordinates O A, 1 1', 2 2', 3 3'.....8 T. Then draw the parabola through the points of intersection thus obtained. This operation takes less time to perform than to describe it. I consider it far superior to the one given on page 159 of your February issue.—MERNÖK.

London, April 18th, 1904.

To the Editor of TECHNICS.

DEAR SIR,—I have been much interested in Mr. Wilfrid J. Lineham's series of articles on Class Diagrams, and have gathered a few points from them. Will you allow me to supplement these with a brief account of my own work in this direction. For many years I have discarded paper and used cloth. I find this much more durable, easier to store, and more convenient to carry about from school to school. I buy a cheap cotton cloth, about 3d. to 3½d. per yard, rather highly filled and very smooth, especially on one side. Every draper does not keep this cloth, and unfortunately I have not been able to learn the exact trade term for it. For line diagrams, I use a water paint made with gum arabic and lamp black for black: vermilion or some other red pigment for red: ultramarine for blue, and so on; mixing with thick gum arabic, making it just so thick that the ink can be nicely worked with the brush, and not thin enough to run on the cloth. For letter diagrams, I use rubber stamps: sets of alphabets can now be bought very cheap. In this way I make very useful class diagrams. While I confine my attention mostly to line digrams, for I am not much of an artist, yet I have shaded diagrams done on cloth, both with water-colour inks and with oil paints.

GEORGE H. HURST.

NOTES.

The Boiling-point of Sulphur

IN measuring high temperatures, and especially when a platinum resistance thermometer or a thermal-junction is used, it is necessary to determine the reading of the instrument, not only at the freezing-point and the boiling-point of water, but also at some third higher temperature, in order to allow for the fact that the resistance in one instrument, and the thermo-electric force in the other, do not increase at a uniform rate with the temperature. For this purpose Professor Callendar proposed to use the boiling-point of sulphur, and this is now generally adopted as the third standard temperature. The boiling-point was determined by Chappius and Harker as 445·2°C as the result of a comparison with the standard gas-thermometer, and when a correction was made for the expansion of the gas-vessel this value was lowered to 444·7°. Recently a series of experiments has been made by Dr. Rothe, at the Reichsanstalt, Charlottenburg; the method adopted was to compare a number of high-temperature mercurial thermometers, containing carbon dioxide under 20 atmospheres pressure, with the standard gas thermometers, and then to use them for measuring the boiling-point of sulphur. Four determinations gave the values 444·66, 444·63, 444·79 and 444·82, the mean agreeing exactly with the figure given by Chappius.

Stability of Hydrogen Peroxide

HYDROGEN peroxide has usually been regarded as an extremely unstable substance, and some surprise was occasioned by the discovery that it is actually present in the flame of burning hydrogen, and can be condensed by allowing the flame to impinge on a block of carbon dioxide snow. At ordinary temperatures the decomposition expressed by the equation $2H_2O_2 = 2H_2O + O_2$ is complete, but Professor Nernst has shown that (as in the combustion of hydrogen and oxygen) there is probably an appreciable amount of back-action at higher temperatures. From thermo-chemical data he has calculated that hydrogen peroxide would be stable if present to the extent of 0·00036% in a mixture of steam and oxygen at 923°C, the percentage rising to 0·028 at 1493°, 0·24 at 2154°, and 0·66% at 2784°. In this way the occurrence of hydrogen peroxide in flames can be accounted for, and no longer appears to be paradoxical; for though the rate of decomposition must be enormously great at these high temperatures, the change is not complete, and small amounts of peroxide would actually be produced by merely mixing steam and oxygen.

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"TECHNICS" COMPETITIONS.

A GOLD MEDAL and £200

To be awarded Annually to the "Technics" Prizeman.

£25 IN PRIZES OFFERED IN THIS ISSUE.

PARTICULARS of 66 competitions have been given in the January, February, March, April, and May numbers of "Technics."

The present number contains particulars of 7 competitions, for which money prizes amounting, in the aggregate, to £25 will be awarded.

At the end of the year, a prize of £200 in cash, and a Gold Medal, will be awarded to the competitor who has shown the most care, thought, and accuracy in the year's competitions.

£25 IN PRIZES.

General Rules.

Competitors are requested to note the following rules:—

All writing must be on foolscap paper. Only one side to be written upon, and a reasonable margin left.

Competitors should see that their drawings are sent either rolled or flat—flat preferred. They must not be creased. They must also be executed in black ink.

N.B.—All drawings, and each page of MS., must bear a *nom-de-plume*, and must be accompanied by a closed envelope containing the name and address of the Competitor. The outside of the envelope must bear the Competitor's *nom-de-plume* only.

The Editors reserve the right to publish, without further payment, contributions that gain prizes. Should any article or drawing that has not gained a prize be published in the magazine, payment will be made at the usual rate.

Should the best answer in any competition be deemed of insufficient merit, the Editors reserve the right to withhold the prize.

All competitions must be addressed to the Competition Department, "Technics," 12, Burleigh Street, Strand, W.C., and must reach these offices not later than July 11th. Results will be published as soon as possible

In each case the work will be submitted to an expert competent to declare which is the best practical suggestion, design, or article.

COMPETITIONS.

THEORY OF CAPILLARITY.

£3 prize for the best answer.

On page 525 reference is made to the fact that the small pores in cotton fibres tend to condense moisture from the atmosphere, thus rendering fabrics made from the cotton moist. Explain precisely why this action occurs.

DYNAMICS.

£3 prize for the best answer.

On page 535 it is stated that if a chemical reaction resulted in a change of mass, a vessel containing the chemical substance, if free to move, would tend either to follow the direction of the

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earth's motion or to fall behind the same, while the reaction occurs. Discuss this point fully, stating the various laws on which your conclusions are founded.

CONSERVATION OF ENERGY.

£3 prize for the best answer.

A man stands in the stern of a boat, travelling with a constant velocity in still water. He throws a stone backwards (*i.e.*, in a direction the opposite to that in which the boat is moving) with a velocity numerically equal to that of the boat. The man does work in projecting the stone; nevertheless, the stone initially possessed kinetic energy in virtue of its motion in common with the boat, while after being thrown, the stone is stationary, its kinetic energy being lost. Is this result consistent with the law of conservation of energy?

ELECTRO-CHEMISTRY.

£3 prize for the best answer.

Give an account of the modern researches on the electrolytic production of chlorate and hypochlorites, referred to on page 553.

ELECTRICITY.

£3 prize for the best answer.

With relation to the question 6, page 609, what would have been the difference of potential between the (+) main and earth, and that between earth and (−) main, if the measurements had been made by an electrostatic instead of an electromagnetic voltmeter? If the two mains had been perfect insulators (*i.e.*, if they had possessed infinite insulation resistance), what would have been the apparent P.D. between each main and earth, if measured (1) by the electromagnetic voltmeter described in the question, and (2) if measured by an electrostatic voltmeter?

STRUCTURAL DESIGN.

£5 for the best set of answers.

1. Prove, by any method you prefer, that the neutral axis of a beam passes through the centroid of each transverse section of the beam.

2. A T bar $3\frac{1}{2}''$ by $3\frac{1}{2}''$ at 9·2 lbs. per foot has a geometrical moment of inertia (or second moment of area) equal to 3 (ins.)^4 The distance of the centroid is $2\frac{1}{2}$ inches from the centre of the stem, and one inch from the outer face of the flange or table. Show that there are two values for the section modulus when the stem is vertical. State which you would use for mild steel, explaining your reasons fully.

3. Explain the considerations which must be taken into account in choosing the depth of a beam for a given span.

4. What is meant by the term "radius of gyration," when applied to a steel stanchion or column?

DYNAMOS AND MOTORS.

£5 prize for the best set of answers.

1. What would be the cause of the following peculiarities in the running of different continuous-current motors? Explain in each case the steps you would take to obtain normal running :—

(*a*) On connecting a motor up to the supply mains, it commences to run in a direction opposite to that for which it was wound, and attains an excessively high speed.

(*b*) A motor sparks badly whatever position the brushes may have, and it is observed that a spark occurs once under each brush during a complete revolution.

(*c*) A motor runs at a rate somewhat less than that for which it was designed, and when running light it is found that an excessively large current is required.

2. Discuss any methods with which you are acquainted for determining the position of an earth on the armature of a motor or dynamo, and compare these with the method described on page 608.

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PERSONAL ITEMS.

PROF. ALEXANDER W. WILLIAMSON, F.R.S., died on Friday, May 6th, at eighty years of age. Although little known to the younger generation of scientists, Prof. Williamson was undoubtedly one of the chief chemists of his day. For many years he was Foreign Secretary to the Royal Society. He commenced his studies under Gmelin, at Heidelberg, but soon joined Liebig, at Giessen. About 1846 he published an important paper on "The Blue Compounds of Cyanogen and Iron," in which the formation of Prussian blue, under various conditions, was described and discussed. Particular attention was devoted to the effect of potassium, which materially affects the dyeing properties of the product. In 1849 Graham offered him the chair of Practical Chemistry, in University College, which he accepted, and occupied for thirty-eight years. In 1850 he published an epoch-making paper on the "Theory of Ætherification." Attempting to substitute carburetted hydrogen for hydrogen in alcohol, by acting on sodium ethylate with the iodide of the carburetted hydrogen which it was desired to introduce, he obtained, to his surprise, a compound possessing none of the properties of an alcohol: it was, indeed, common ether, $C_4H_{10}O$. Owing to the clear and concise reasoning used by Williamson in describing his discovery and the conclusions which he drew from it, chemists at once recognised the importance of the advance achieved. He was elected a Fellow of the Royal Society in 1855, and served on the Council from 1859 to 1861, again from 1869 to 1871, and for a third time from 1873 to 1890. In 1889—1890 he was made Vice-President. He was twice President of the Chemical Society, from 1863 to 1865, and once more from 1869 to 1871. His influence was exerted to establish the series of abstracts of foreign chemical literature, which still forms a valuable feature of the "Journal of the Chemical Society."

SIR H. M. STANLEY died on Tuesday, May 10th, at sixty-three years of age. His work is too well known to require more than a brief mention: his classical volume, "How I found Livingstone," is known to all readers of travels. He was instrumental in clearing up much of the mystery which hung about the interior of the "Dark Continent," especially with regard to the region in the neighbourhood of Lakes Victoria Nyanza, Albert Nyanza, and Tanganyika. Stanley had scarcely landed in England at the termination of this expedition, before the King of the Belgians asked his aid in opening up the Congo. In the following year (1879) Stanley proceeded to the Congo, where his explorations served to found the Congo Free State, under the King of the Belgians. Stanley's search in Africa for Emin Pasha, in 1887, must still be in the minds of everyone. The results of this expedition were described in the volume, "In Darkest Africa."

PROF. VAN'T HOFF, through the medium of the *Zeitschrift für Physikalische Chemie*, offers a prize of £60 for the best and most complete synopsis of the literature of catalytic phenomena. The last day for the receipt of papers in this competition is June 30th, 1905: the papers must be addressed to the Editors of the *Zeitschrift*, 2, Linnéstrasse, Leipzig. The competition is to be decided by Profs. van't Hoff, Arrhenius, and Ostwald.

THE British Fire Prevention Committee offers a gold medal and £20 in cash for the best tale for children, calculated to impress them with the danger of playing with matches or fire. Two silver and four bronze medals will also be awarded for meritorious essays on the same subject. The conditions can be obtained by sending a stamped and addressed envelope to the Committee's offices, 1, Waterloo Place, London, S.W.

THE LANCASHIRE COUNTY COUNCIL has arranged for fishermen from the Lancashire coast to attend, in batches of fifteen at a time, at the Piel (Barrow) Hatchery and Marine Laboratory, to be instructed in the habits and conditions of breeding of various kinds of fish. The course lasts a fortnight, during which time the Council allows each man £5 towards his expenses. The course is under the direction of Prof. W. A. Herdman, F.R.S.

FERRO-CONCRETE railway sleepers are now being tried on the railway from Voiron to Saint Béron, France. According to the *Génie Civil*, the sleepers are 5·9 ft. long, by 7 ins. wide and 5½ ins. deep. The concrete consists of 33 kilograms of cement mixed with 40 litres of sand: the steel bars weigh 8·4 kilograms per sleeper. Each sleeper costs 3*s.* 9*d.*, so that they are not much dearer than wooden sleepers, while their life is four or five times as long.

A REMARKABLE electric transmission line is described by Mr. B. Wiley, in the *Electrical World and Engineer*. This line is carried from the Carrie furnaces, Braddock, across the Monongahela River to the Homestead Steel Works. The cables are of aluminium, 960 ft. long, and about one inch in diameter. They weigh 0·736 lbs. per foot, and their conductivity is about 63 per cent. of that of a copper cable of equal section. The aluminium has a strength of 32,000 lbs. per square inch.

THE AUTOMOBILE CLUB are arranging for trials of motor boats, on lines somewhat similar to their previous "reliability trials" of motor cars. The committee includes Sir J. T. Thornycroft, F.R.S., Mr. A. F. Yarrow, Mr. S. Edge, and other well-known authorities. The trial has been fixed for July 26th and 27th next, at Southampton Water.

A CONVERSAZIONE was held at the South Western Polytechnic, Manresa Road, Chelsea, on May 7th. The well-equipped engineering laboratories excited a great deal of interest.

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RESULTS OF MARCH COMPETITIONS.

GENERAL COMPETITIONS.

No. 1.—**The best original photographic print of a group of flowers showing the correct colour values in black and white. Competitors may choose what flowers they like, but the difficulty of correctly photographing them will be taken into account in awarding the prize.**

PRIZE, £3.—Adam H. Smith, Winton Lodge, High Road, Wealdstone, Middlesex.

HONOURABLE MENTION :—A. V. Hussey.

No. 2.—**Give a classification of dyes under the heads of the various fabrics, such as cotton, wool, silk, etc., for which they are suitable. Explain, so far as you can, the scientific principles which determine the suitability of various dyes.**

PRIZE, £3.—Arthur H. Bird, 21, The Palatinate, New Kent Road, S.E.

SPECIAL HONOURABLE MENTION :— Ralph Daintree, Thomas Edwin Bradbury.

HONOURABLE MENTION :- R. H. Greaves.

No. 3.—**Describe, with diagrams, the way in which cotton-spinning machinery utilises the properties of cotton fibres described in Mr. Dawson's article.**

PRIZE, £4.—Frederic Stones, Textile Department, School of Technology, Manchester.

No. 4.—**Describe present methods of liquefying gases, with diagrams of apparatus used. State the approximate proportion of the air pumped through the machine which is liquefied, and discuss the lines along which improvements may be expected to proceed.**

PRIZE, £4.—H. H. Francis Hyndman, 27, Pembroke Square, Kensington, W.

No. 5.—**A house is built in an exposed situation, and has latticed windows. Give a working drawing of the design of the windows in order to prevent rain from being forced through the crevices by the wind.**

PRIZE, £4.— James Herbert Belfrage, 9, Trafalgar Square, Chelsea, S.W.

SPECIAL HONOURABLE MENTION :—Harold Slicer.

HONOURABLE MENTION:—Geo. Cross.

No. 6.—**Give a description of our present knowledge of electrons, and discuss the experimental data on which this knowledge is founded.**

PRIZE, £4.—Edgar P. Hedley, Royal College of Science, Dublin.

SPECIAL HONOURABLE MENTION :—George Herbert Martyn ; George S. Whitby.

HONOURABLE MENTION :—Thomas Royds ; Geo. J. Denbigh ; Herbert J. Lant.

No. 7. -**Describe the characteristic features of a modern producer gas plant, with working drawings.**

PRIZE, £4.— Frederic P. Marsden, East View, Newport, Shropshire.

SPECIAL HONOURABLE MENTION :—H. G. Lester ; C. P. Finn ; Richard Colell ; Earby Dalton.

No. 8.—**Compare the relative economies of gas (with and without mantles), electric glow lamps, Nernst lamps, and arc lamps, when used for illuminating purposes. Support your contentions with figures, and state the particular circumstances to which each form of illumination is most suitable.**

PRIZE, £4.—Percy Alfred Spalding, 14, Torrington Square, W.C.

SPECIAL HONOURABLE MENTION :—A. H. Stewart ; Samuel Lees.

No. 9.—**Special Competitions.**—(See below).

SPECIAL COMPETITIONS.

I.—Continuous-Current Dynamo.

PRIZE, £5.—This prize has been equally divided between two competitors :—I. M. Chippendale, Scholes, Near Leeds ; William J. Williams, 528, Caledonian Road, N.

SPECIAL HONOURABLE MENTION :—A. P. Chalkley, A. H. Stewart.

II.—Questions on Photography.

PRIZE, £5.—H. H. Francis Hyndman, 27, Pembroke Square, Kensington, W.

SPECIAL HONOURABLE MENTION :—S. I. Crookes.

HONOURABLE MENTION :—W. Cassels Brown ; Geo. J. Denbigh.

III.—Questions on Casting.

PRIZE, £5.—John Swain, Greenwood, Buxton.

SPECIAL HONOURABLE MENTION :—John R. Moorhouse ; H. G. Lester.

IV.—Theory of Structural Design.

PRIZE, £5. — Frank S. Easton, 1, Knowe Terrace, Pollokshields, Glasgow.

SPECIAL HONOURABLE MENTION :—Henry James Jones ; John T. Wight ; T. Bonallo.

HONOURABLE MENTION :—A. C. B. Smith ; Stanley S. Elliott ; W. Jno. Richards ; D. E. Synan.

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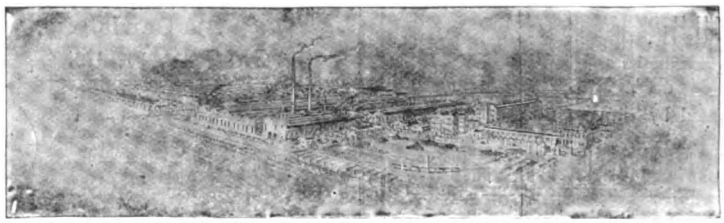

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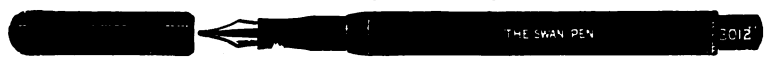

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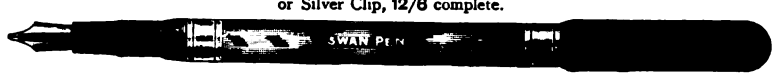

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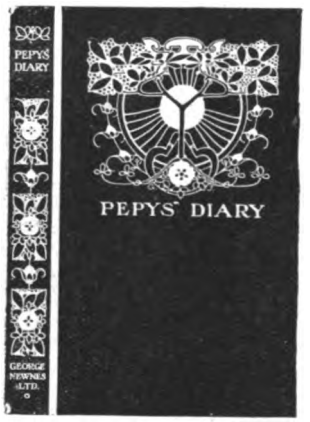

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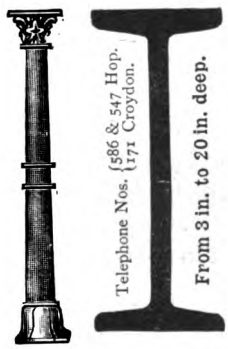

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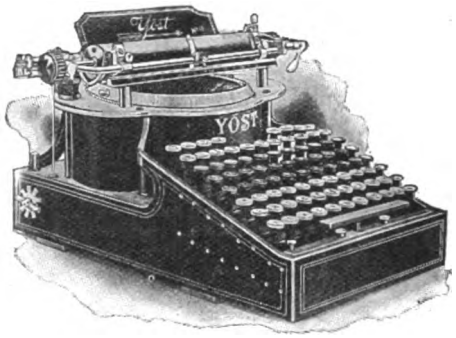

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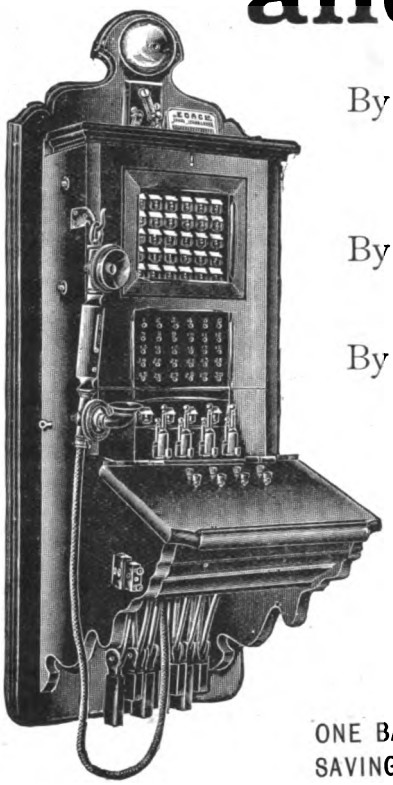

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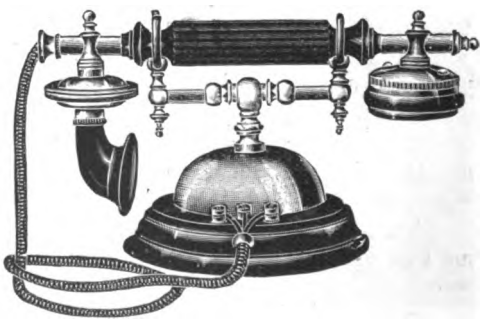

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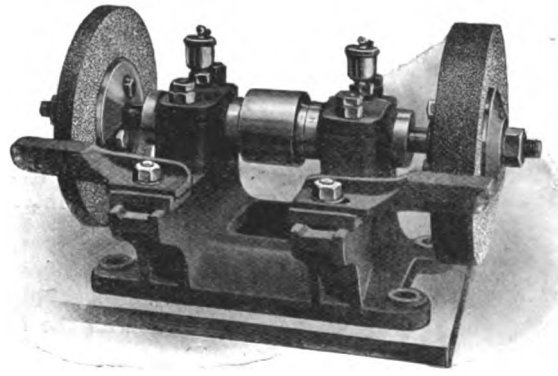

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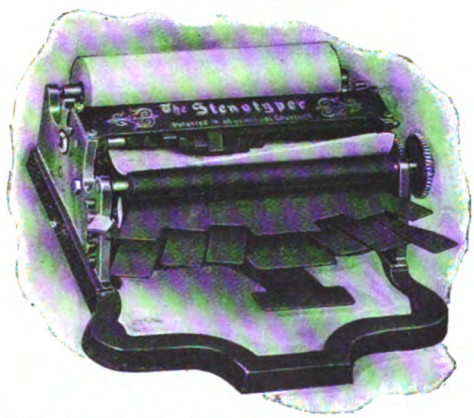

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A MAGAZINE FOR TECHNICAL STUDENTS.

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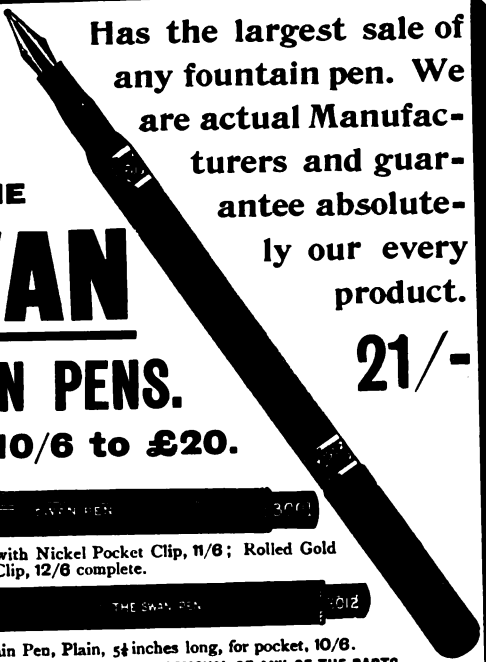

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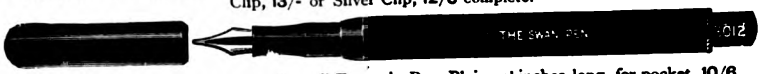

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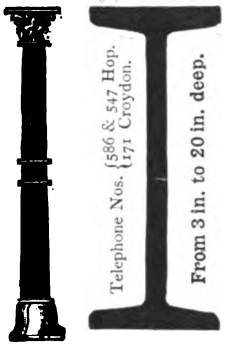

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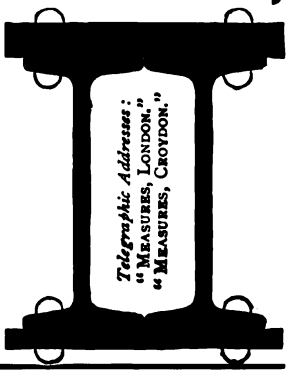

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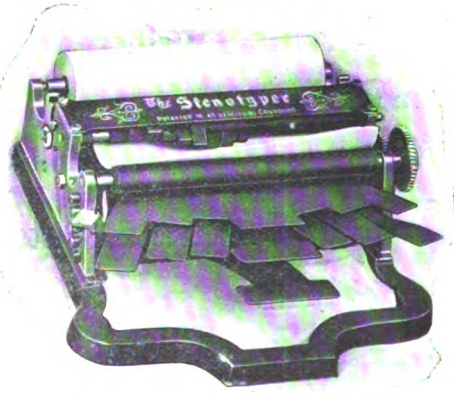

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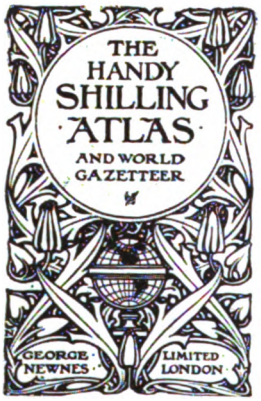

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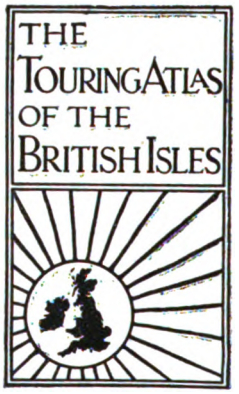

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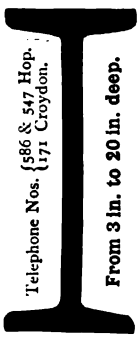

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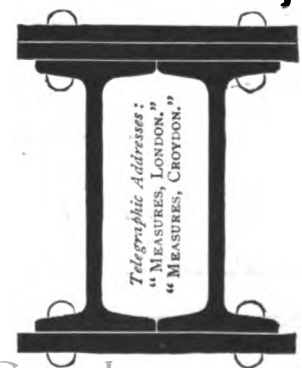

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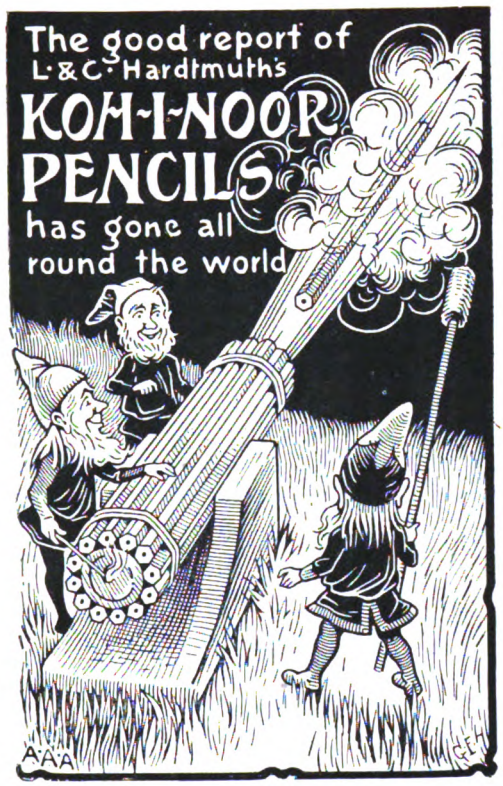

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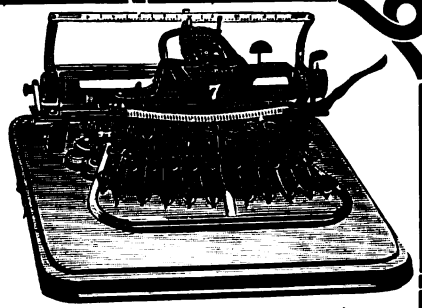

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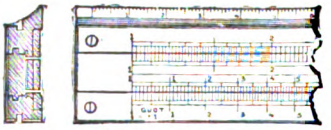

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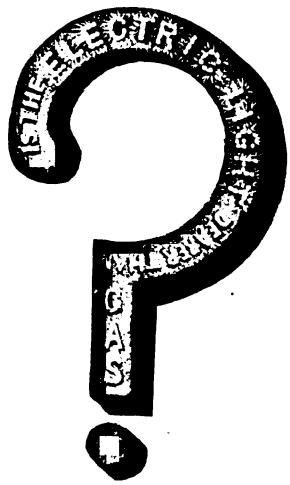

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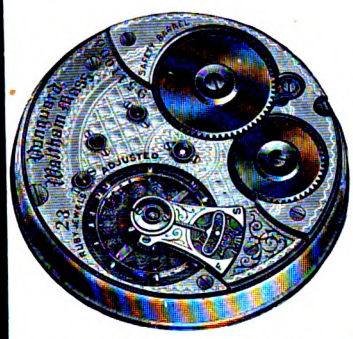

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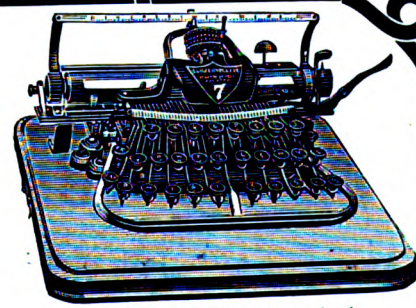

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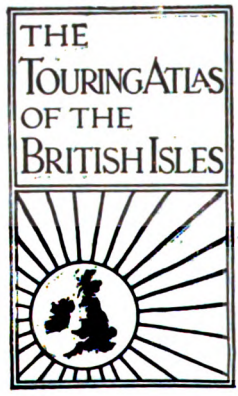

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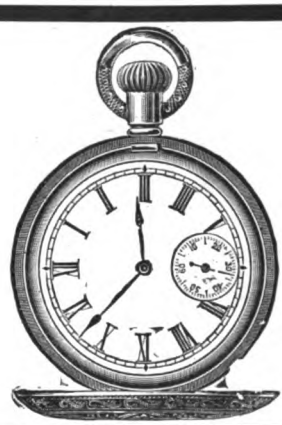

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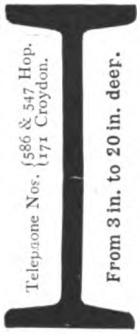

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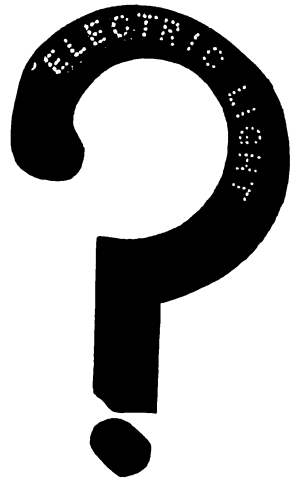

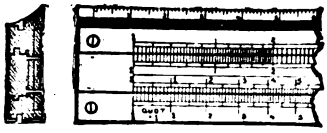

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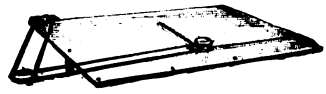

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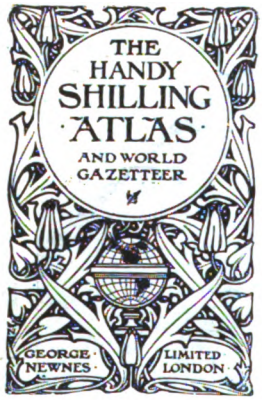

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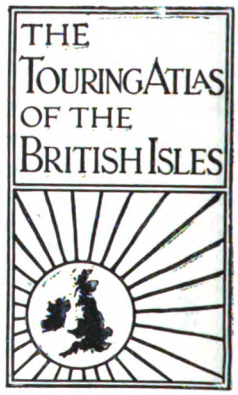

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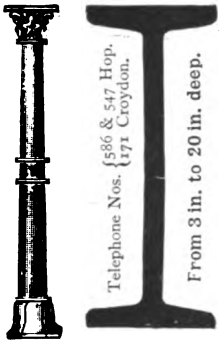

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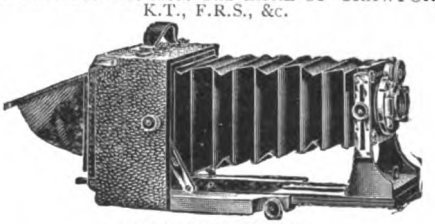

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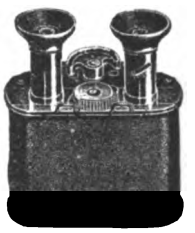

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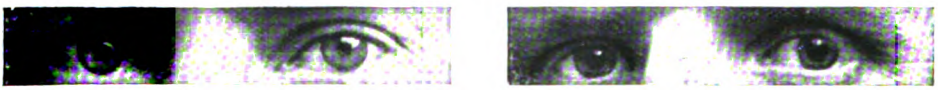

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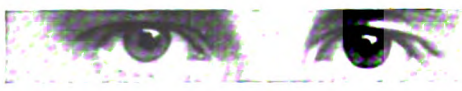
CAPTAIN  **June, 6d.**

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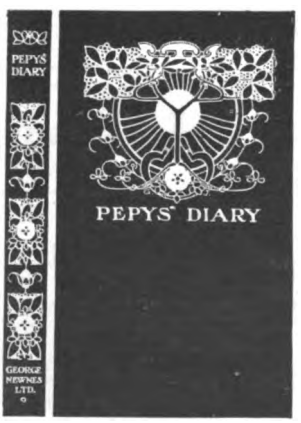

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